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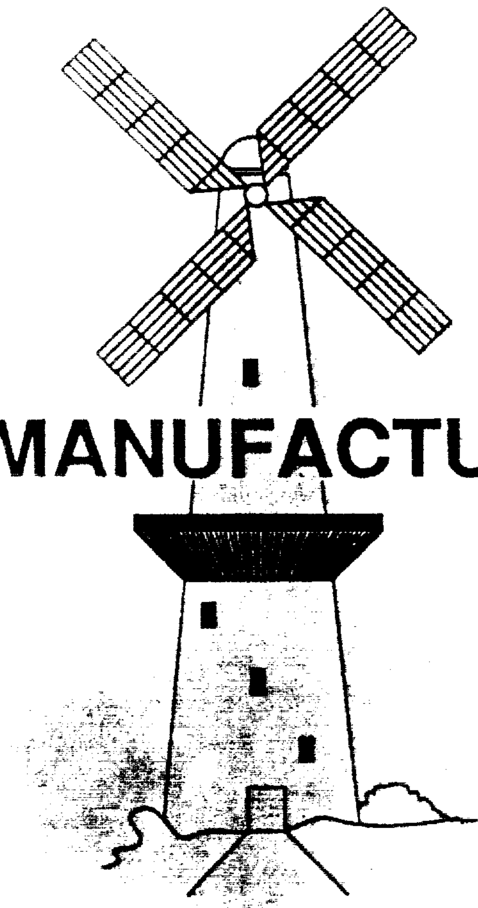
Feasibility Study Report



HI-MILL MANUFACTURING CO.

1704 HIGHLAND ROAD
HIGHLAND, MICHIGAN

GERAGHTY
& MILLER, INC.
Environmental Services

FEASIBILITY STUDY
FOR THE
HI-MILL MANUFACTURING FACILITY
HIGHLAND, MICHIGAN

JULY 1993

Prepared for

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FEASIBILITY STUDY REPORT
HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

July 28, 1993

Geraghty & Miller, Inc. is submitting this Feasibility Study Report on behalf of the Hi-Mill Manufacturing Company for work performed at their Highland, Michigan, facility. This report was prepared in conformance with Geraghty & Miller's strict quality assurance and quality control procedures to ensure that the report meets industry standards in terms of the methods used and the information presented. If you have any questions concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

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APPENDICES

1.0 INTRODUCTION

The Hi-Mill Manufacturing Company (Hi-Mill), located at 1704 Highland Road in Highland Township, Michigan (Figure 1), has engaged in the fabrication of copper, aluminum, and brass tubing parts and fittings since it was first established in 1946. Wastewater generated as a result of plant processing operations was historically discharged into two evaporation ponds which were formerly located at the rear of the facility (Figure 2). The Michigan Department of Natural Resources (MDNR) conducted several investigations at the Hi-Mill facility between 1972 and 1982 to determine the potential impact of plant operations on the surrounding site soils, ground water and surface water. In 1983, Hi-Mill was required, by the MDNR, to close both of the wastewater lagoons.

In 1988 the Oakland County Health Department (OCHD) and the Michigan Department of Public Health (MDPH) collected several water samples from two supply wells used to furnish water for the Hi-Mill facility (Figure 2). While neither the OCHD or MDPH detected concentrations of metals in excess of the drinking water standards, they did detect the presence of the volatile organic compounds (VOCs) benzene, trihalomethanes, trichloroethene (TCE), and 1,2-dichloroethene (1,2-DCE). As a result of these investigations, the MDPH notified Hi-Mill that the water produced from these wells was not suitable for human consumption, and both supply wells were subsequently abandoned. The presence of TCE and 1,2-DCE in the supply wells was suspected to have been related to the use of degreasing solvents as part of Hi-Mill's manufacturing processes.

As a result of the investigations conducted by the MDNR, the OCHD, and the MDPH, a limited hydrogeologic investigation of the site was performed in 1988 by Techna Corporation (Techna) of Plymouth, Michigan. This limited investigation was followed by a full-scale remedial investigation (RI) of the site in 1990, which was also performed by Techna. Among the findings of the Techna RI, several VOCs were detected in the site soils and ground water, in particular TCE and 1,2-DCE. A wide variety of metals were also discovered in the site soils, particularly near the former evaporation ponds.

Geraghty & Miller, Inc. (Geraghty & Miller) was initially retained to perform a review of Techna's work in 1990. Following this review, Geraghty & Miller conducted a Phase II RI of the Hi-Mill site between 1990 and 1992. During the Phase II investigation, Geraghty & Miller further delineated the vertical and horizontal extent of VOC and metals impacted soils, ground water, and surface water. During the Phase II investigation, the volatile organic compounds TCE, 1,2-DCE, and vinyl chloride were detected in concentration in ground water and site soils in areas immediately adjacent to the plant building and beneath the Michigan State Route 59 (M-59) roadway (Figure 3). It was also discovered that an accidental release of approximately 250 gallons of chlorinated solvent-based degreaser had occurred between 1978 and 1980 during the construction of a new addition to the plant building (Figure 2). It was concluded that the bulk of the chlorinated solvents detected in the site ground water was related to this accidental release. The final Remedial Investigation Report prepared by Geraghty & Miller was approved by the United States Environmental Protection Agency (USEPA) in March 1993.

Pursuant to the completion of the Hi-Mill RI, this Feasibility Study has been developed to develop and evaluate potential remedial alternatives which could be implemented to address the presence of volatile organic compounds in the site soils and ground water. Presented in the following section is a specific discussion related to the purpose of this report.

1.1 PURPOSE OF REPORT

This Feasibility Study (FS) has been prepared in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. CERCLA established a federal program with a broad authority to address the release of hazardous substances into the environment. Specific program requirements are described in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This FS has been written to be consistent with CERCLA, the NCP, and other appropriate federal and state requirements.

Presented in the following section is a discussion of the regulatory framework for this site with respect to the National Contingency Plan (NCP).

1.2 REGULATORY FRAMEWORK

Section 300.430(e) of the NCP outlines the requirements for the performance of a CERCLA FS. The stated primary objective of the FS is "to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected." The USEPA, in consultation with other federal and state agencies, is the designated "decision-maker" for CERCLA remedies. Some specific NCP requirements for the development of FS alternatives are summarized below.

Requirement	*NCP Citation*
Alternatives must protect human health and the environment through waste recycling or by eliminating, reducing, and/or controlling risks from identified exposure pathways	300.430(e)(2)

Preliminary remediation goals are based on ARARs and other information such as risk-based calculations.	300.430(e)(2)(i)
For ground-water remediation, develop a limited number of alternatives which achieve cleanup levels within different time periods, utilizing one or more technologies.	300.430(3)(4)
Develop one or more alternative(s) using innovative treatment technologies if they offer the potential for comparable or superior performance or implementability, fewer adverse impacts, or lower costs for similar levels of performance than demonstrated technologies.	300.430(3)(5)
Develop the "no action" alternative	300.430(e)(7)
Use long- and short-term effectiveness, implementability, and cost as factors to develop and screen alternatives.	
Use the "nine criteria" to evaluate alternatives in detail.	300.430(e)(9)

The appropriate decision-maker (USEPA), in consultation with other federal agencies and the State of Michigan, will use the nine criteria to select an alternative evaluated in this FS for implementation at the site. These criteria have been grouped into three major categories as follows:

- *Threshold criteria:*
  1. Overall protection of human health and the environment
  2. Compliance with ARARs

· *Primary balancing criteria:*	3.	Long-term effectiveness and permanence
	4.	Reduction of toxicity, mobility, or volume
	5.	Short-term effectiveness
	6.	Implementability
	7.	Cost
· *Modifying criteria:*	8.	State acceptance
	9.	Community acceptance

A definition of the nine evaluation criteria and the relative importance of the three groups of criteria outlined above are included in Section 5.0 and 6.0 of this FS.

1.3 SITE BACKGROUND

This section presents a description of the Hi-Mill site, a brief summary of the site history, and a listing of previous investigations conducted at the facility.

1.3.1 Site Description

The Hi-Mill Manufacturing facility is located at 1704 Highland Road (M-59) in Highland Township, Oakland County, Michigan (Figure 1). The manufacturing facility itself occupies approximately 4.5 acres and is located within Section 23, T7N, R18W at an elevation of about 1010 feet (ft) above National Geodetic Vertical Datum (NGVD) (Figure 2).

The Hi-Mill Manufacturing property is dominated by the manufacturing facility and a paved parking area. The primary function of the Hi-Mill Manufacturing plant is the production of assorted tubular parts. The factory has been expanded several times since its original construction in 1946 and houses administrative offices and raw material storage and preparation areas in addition to actual production facilities. Paved parking areas occupy the northeast corner of the property and a portion of the southwest margin of the site. The remainder of the property is covered by vegetation.

The Hi-Mill Manufacturing site is bounded to the northwest by Michigan State Route 59 (M-59) and, generally, on all other sides by the Highland State Recreation Area, which is owned and operated by the MDNR. Property located to the northwest of the site across M-59 is also part of the Highland State Recreation Area. A manufacturing facility owned by Numatics, Inc. is located approximately 1000 ft northeast of the Hi-Mill Manufacturing property. Correspondence provided through the Livonia District office of the MDNR indicates that Numatics, Inc. is engaged in the cleaning and assembling of small parts used in air control valves (MDNR Fact Sheet, 1987). Numatics, Inc. reportedly discharges process wastewater to a drain and septic field located on Numatics property. A private land owner, Mr. Dan Teeples of Waterbury Road, owns some of the land adjoining part of the Hi-Mill Manufacturing facility to the southeast.

Target Pond, a marshy area of approximately 8 to 10 acres, is located approximately 200 ft east of the site building. Situated approximately 450 ft south of the facility is the North Arm of Waterbury Lake. The North Arm is drained by Waterbury Lake which is located at a distance of some 900 ft south of the Hi-Mill Manufacturing factory. A lightly wooded area is present immediately behind the site buildings to the southeast.

The area surrounding the Hi-Mill Manufacturing facility is rural and, thus, sparsely populated. The nearest dwellings are located approximately 2000 ft east-southeast of the site along Waterbury Road. The population of Highland Township is roughly 17,000 to 19,000 people. The township has little commercial development and few municipal services. Many of the area inhabitants obtain fresh drinking water from domestic water wells and dispose of sanitary sewage through septic systems generally located on their residential property. Hi-Mill

Manufacturing disposes of sanitary sewage by way of a septic drain field located behind the site building.

The topography of the area surrounding Hi-Mill Manufacturing is reflective of the glaciation which was active over 16,000 years ago. The area landscape is dotted with numerous small lakes and wetland areas which were created during the last ice age as huge blocks of ice were left behind at discrete locations as the main ice sheets retreated northward. These blocks of ice melted in place forming the small basins which now act to retain precipitation and runoff forming the present-day surface-water features. The topography of the Hi-Mill Manufacturing property itself is relatively flat lying with maximum relief of approximately 6 ft across the site. The land surface across the back of the property generally slopes toward adjacent Target Pond (Figure 2).

Soils in the region encompassing the site are comprised of clays, silts, sands, and gravels deposited by glacial ice sheets. These sediments may be as thick as 300 ft in some areas. The soils and geology of the Hi-Mill Manufacturing facility and adjacent study area will be discussed in greater detail in a later section of this report.

1.3.2 Site History

Hi-Mill Manufacturing has engaged in the fabrication of copper-, aluminum-, and brass-tubing parts and fittings since it was first established in 1946. Processing operations have included or currently include nitric and sulfuric acid cleaning and brightening, chromic acid washing, and degreasing using chlorinated solvents. Soldering activities do not make use of tin-lead solder but employ silver solder or aluminum-bar brazing instead. However, an MDNR-activity report dated April 20, 1972, indicates that Hi-Mill Manufacturing personnel informed the MDNR that lead had been used in the Hi-Mill Manufacturing process for a single project lasting about one month.

Wastewater from plant operations was historically discharged to two lagoons located behind the building to the southeast; the former locations are shown in Figure 2. Process wastewater consisting chiefly of water and diluted acid-brightening solutions were discharged to the largest of the two site lagoons (the bottom of which was keyed in the top of the brown clay and approximately 90 ft x 90 ft) prior to 1960 (exact date unknown) until sometime in 1981. The base of this lagoon was reportedly excavated approximately 6 ft into an underlying clay unit. A second, smaller lagoon was constructed in the fall of 1976 south of the existing wastewater lagoon (Figure 2). This second lagoon was constructed to accept overflow from the larger, original lagoon. Although the lagoons were designed to serve as evaporation basins only, wastewater from these two lagoons was unintentionally discharged into Target Pond due to overflow from the impoundment area, particularly during periods of high rainfall. Between 1981 and 1983, Hi-Mill Manufacturing attempted to dissipate the volume of wastewater effluent more effectively by discharging water contained within the lagoons through spray nozzles located both atop the roof of the production facility and along portions of an 8-foot high fence which surrounds the rear of the property.

In September of 1983, Hi-Mill Manufacturing submitted a request to the MDNR to remove the sludge from the larger of the two lagoons along with adjacent soils and to backfill the area with clean fill. Following approval by the MDNR, the sludge and related soils were removed between November and December 1983 by the General Oil Company of Livonia, Michigan. In addition to the removal of the sludge, soils located along the sides of the lagoon were excavated along with approximately one foot of clay from the bottom to ensure that all potentially contaminated material had been removed. All of the excavated soils and sludge were transported to an appropriate disposal facility. All operations during excavation were monitored by representatives of the MDNR, and the excavated lagoon area was inspected by the MDNR prior to final closure. The smaller lagoon completed in 1976 was not evident during reclamation of the large lagoon and, as such, was not excavated. While the fate of the smaller impoundment is not currently known, it is possible that portions of the lagoon were regraded across the property by either natural and/or proactive means.

Degreasing of fabricated tubular parts has been a part of Hi-Mill Manufacturing's production process since prior to 1970 (exact date unknown). A trichloroethylene-based solvent was received and stored in an aboveground tank located approximately 50 ft east of the present production building. Solvent was transferred to the degreasing equipment located in the northeast section of the production facility. Between 1978 and 1980 (exact date unknown), activities related to the construction of an addition on the northeast side of the building resulted in the damage of the solvent delivery line between a former aboveground storage tank and degreaser (as shown in Figure 2). As a result of the damage, a maximum of 250 gallons of solvent leaked from the damaged underground product line. The product loss was discovered the following work day, and the damaged underground product line was replaced with an aboveground product line. The locations of various existing and former storage tanks and degreasing units are shown on Figure 4.

The Hi-Mill Manufacturing facility previously obtained supplies of fresh water from two production wells formerly located near the northeast and southwest corners of the building, respectively (Figure 2). The well located northeast of the building was installed shortly after the commencement of activities at the facility in 1946 (exact date unknown) and was approximately 89 ft deep. The other well, located southwest of the facility, was installed to a depth of 50 ft below land surface (bls) in January 1969. The water formerly supplied by these two wells was used for drinking, sanitary, and processing purposes. Between March and November 1988, the OCHD and the MDPH sampled and analyzed both of the former production wells a total of seven times. Although the chemistry of the water samples collected from both wells differed somewhat over this period, varying concentrations of benzene and TCE were found in the northeast production well, while TCE and 1,2-DCE were detected several times in the well located southwest of the factory. As a result of these findings, the MDPH notified Hi-

Mill Manufacturing that the quality of the water provided by the two wells was not suitable for continued use by its employees. Consequently, both wells were decommissioned by Jim Layman of Layman Drilling in December 1989. A new production well was installed away from the site building to serve as a replacement supply of potable water for the facility. The new well (the location of which is shown in Figure 2), installed in January 1989 by Layman Drilling, is 6 inches in diameter and was screened at an interval of from 99 ft to 107 ft bls.

1.3.3 Previous Investigations

Contained within this section is a synopsis of the investigations conducted thus far at the Hi-Mill Manufacturing facility. A total of nine investigations related to the identification of contamination and/or the assessment/control of chemical species within the ground water and soil at Hi-Mill Manufacturing, has been delineated. Presented below, in chronological order, are descriptions of each of these nine distinct investigations.

1.3.3.1 MDNR Investigations - 1972 to 1978

The MDNR conducted an ongoing investigation into various aspects of operations at the Hi-Mill Manufacturing facility during this period. In April 1972, representatives of the MDNR investigated a complaint by a Hi-Mill Manufacturing employee that the plant water wells might be contaminated. Samples of the ground water from the two site production wells and the adjacent Target Pond were collected by the MDNR and submitted for analysis. The MDNR reported that "slightly elevated" concentrations of copper were measured in one well, and elevated levels of copper and nitrates were detected in the waters of Target Pond. Additional surface-water samples were collected from Target Pond by MDNR officials in October 1975, and again in May, November, and December of 1976. In both instances, analyses of these samples indicated that the concentrations of copper, aluminum, zinc, chromium, and nitrates were all elevated (Techna Corp. 1990).

1.3.3.2 MDNR Study of the Target Pond/Wetland Area - 1976

In April 1976, personnel from the MDNR Water Quality Division initiated a study of the Target Pond/wetland area adjacent to Hi-Mill Manufacturing. MDNR investigated both the water and soils from Target Pond, as well as the ground-water quality from one of the Hi-Mill Manufacturing water supply wells. Background sediment samples were collected from Pontiac Lake, located approximately 7.5 miles northeast of the Hi-Mill Manufacturing site.

Analyses of the ground-water samples collected from the site production well failed to indicate the presence of elevated levels of metals as had been suggested during past investigations. The concentrations of nitrate, nitrite, ammonia, chromium, copper, zinc, and aluminum in water samples collected from the lagoon and marsh waters were reported as elevated, however, by the MDNR (Techna Corp. 1990). Elevated concentrations of total chromium, copper, and aluminum were also reported in sediment samples collected from both the lagoon and marsh sediments.

1.3.3.3 MDNR Hydrogeological Investigation - 1981/1982

A hydrogeological investigation of the Hi-Mill Manufacturing facility was conducted by representatives of the MDNR Water Quality Division in August 1982. The investigation consisted of the installation of six, 1-1/4 inch polyvinyl chloride (PVC) monitoring wells into the upper clay layer located approximately 4 to 7 ft below grade at the Hi-Mill Manufacturing site. The piezometers were placed along the eastern and southern margins of the property, adjacent to the Highland State Recreation Area. The MDNR utilized these wells for the collection of ground-water-quality samples and the measurement of ground-water elevations.

The MDNR concluded that the flow of water in the upper perched unit was generally toward the Target Pond/wetland area. Ground-water samples collected from wells located near the site lagoon were found to contain elevated levels of copper, total chromium, zinc, and aluminum (Techna Corp. 1990).

1.3.3.4 Lagoon Closure - 1983

Hi-Mill Manufacturing submitted correspondence in September 1983 to the MDNR that requested approval to initiate the excavation and backfilling of the evaporation lagoons located behind the Hi-Mill Manufacturing facility. Following approval by the MDNR, excavation and backfilling operations were completed between November and December 1983 by the General Oil Company of Livonia, Michigan. Sludge was removed from the larger of the two site lagoons along with soil from the sides and bottom of the impoundment. Approximately one foot of clay was excavated from the bottom of the lagoon to ensure that all potentially contaminated materials had been removed. All excavation activities were monitored by representatives of the MDNR, who inspected the lagoon area prior to the commencement of backfilling operations. A reported quantity of 142 cubic yards of soil, 34,400 gallons of sludge, and 63,300 gallons of water were removed from the lagoon and transported to an appropriate disposal facility (Techna Corp. 1990). The smaller of the two lagoons was not evident during these operations and, as such, was not excavated. While the status of the small overflow lagoon is not specifically known, it is speculated that the lagoon may have been regraded flush with the existing topography by either natural and/or proactive means.

1.3.3.5 MDNR Ecological Survey - 1984

An ecological survey was conducted in April 1984 by representatives of the MDNR Surface Water Quality Division. The ecological survey consisted of a limited investigation of the biological, surface-water, and sediment characteristics of the Target Pond/wetland area and nearby Waterbury Lake. An inspection of the plant roof and parking areas was also conducted to assess potential runoff patterns. The surface-water and bottom-sediment samples collected were analyzed for aluminum, arsenic, iron, mercury, zinc, cadmium, total chromium, copper, nickel, and lead. Benthic and phytoplankton organisms were also collected and visually identified on-site and by laboratory microscopy.

The chemical analyses of surface-water samples collected from Target Pond indicated that the concentrations of zinc, chromium, and copper were higher than those measured in the background samples collected from Waterbury Lake. The levels of chromium and zinc did not exceed freshwater aquatic life criteria, but the concentration of copper exceeded the chronic criteria for warm-water fish (Techna Corp. 1990).

Analyses of sediment samples collected from Target Pond were reported to contain concentrations of aluminum, zinc, total chromium, and copper in excess of those detected in the background sediment samples obtained from Waterbury Lake. No significant difference in concentration was found between the Target Pond and Waterbury Lake samples analyzed for arsenic, mercury, cadmium, nickel, and lead (Techna Corp. 1990).

The MDNR reported finding few benthic or other bottom-dwelling organisms during their biological survey of Target Pond. Data were insufficient to determine if the absence of these organisms was due to water-level fluctuations within the wetland or impact by the Hi-Mill Manufacturing facility. The MDNR reported finding zooplankton at both of their sampling stations. *Daphnia* (a copper-sensitive organism) were found in quantity as were a variety of filamentous green algae, flagellates, other algae, and macrophytes (Techna Corp. 1990).
The MDNR ecological survey report concluded that:

1. Waterbury Lake was not interacting via a surface water connection with the Target Pond/wetland area and was not impacted by activities at the Hi-Mill Manufacturing facility.

2. Surface-water samples from Target Pond generally contained higher concentrations of heavy metals than did background samples collected from Waterbury Lake.

3. Concentrations of copper in Target Pond waters exceeded the chronic criteria for warm water species of fresh-water aquatic life.

4. Concentrations of heavy metals contained within the sediments of Target Pond exceeded the background concentrations measured in sediments collected from Waterbury Lake.

5. Algae and zooplankton were found to be abundant in the waters of Target Pond; however, bottom-dwelling organisms were limited to pollutant-tolerant forms. Insufficient data exist as to whether the lack of diversity among benthic organisms was due to natural fluctuations in water and nutrient supply or impact from Hi-Mill Manufacturing.

In its February 1985, Report, the MDNR recommended the following:

1) The sources of heavy metals entering Target Pond from Hi-Mill should be "minimized."

2) The existing lagoons should be filled.

3) A determination should be made as to whether ground water should be purged.

1.3.3.6 Oakland County Health Department Well Survey - 1988

The OCHD and the MDPH collected a total of seven water samples from the two site production wells between March 1988 and November 1988. Samples were analyzed for general parameters, metals, and VOCs. The OCHD and MDPH reportedly did not detect concentrations of metals in excess of drinking water standards; however, trihalomethanes and benzene were both detected in a composite sample of the two wells collected in March 1988.

While no VOCs were detected in the composite sample collected in June 1988, TCE was measured at levels near the detection limit of 1 microgram/liter (μg/L) in the well located at the southwest corner of the building during the July 1988 sampling event. Benzene was detected during the same sampling event in the well formerly located at the northeast margin of the Hi-Mill Manufacturing property.

Analysis of a composite sample collected in September 1988, did not indicate the presence of VOCs; however, another set of samples collected from each well in the following month of October was found to contain TCE in both wells and *cis*-1,2-DCE in the southwest well.

Subsequent water samples collected during the months of October and November indicated the presence of TCE in both the northeast and southwest supply wells and that 1,2-DCE (a degradation product of TCE) was also present in the southwest site well.

The MDPH notified Hi-Mill Manufacturing on November 7, 1988, that the results of the ground-water sampling and analysis of both wells indicated that water from these wells was not suitable for human consumption. Hi-Mill Manufacturing was instructed by MDPH to warn employees of the quality of the water, to provide a supply of bottled water for drinking purposes, to abandon both of the existing wells, and to install a new production well further away from the facility to serve as a replacement source of potable water.

1.3.3.7 Techna Corporation Hydrogeological Study - 1988

A limited hydrogeological assessment of the Hi-Mill Manufacturing site was conducted by Techna in November 1988 in response to the disclosure of the presence of chlorinated solvents in the Hi-Mill Manufacturing supply wells. The stated objectives of the Techna hydrogeological assessment were as follows:

1. To determine the subsurface stratigraphy to a depth of 100 ft bls.

2. To collect and analyze ground-water samples in order to delineate the distribution of chlorinated solvents below the water table.

3. To determine the ground-water flow direction in the deep aquifer system(s).

4. To evaluate the hydraulic interconnection between hydrostratigraphic units at depth.

5. To assess the potential for contaminants in the surficial saturated zones near the supply wells.

Three boreholes were completed by Techna to a depth of approximately 100 ft bls. These boreholes were located at the northeast corner of the property, at the west corner of the property, and south of the production building in the vicinity of the former lagoon. Soils were logged during drilling, and temporary, 2-inch diameter PVC monitoring wells were installed at each location.

Techna reported that the general subsurface stratigraphy consisted of 1.5 ft to 3 ft of fill underlain by a thickness of from 26 ft to 45 ft of stiff, moist, silty, blue clay. Techna indicated that this clay layer was contiguous at the northeast and south boring localities. However, an approximately 5-foot layer of fine, silty sand was found at the west boring location which was contained within the clay stratum at a depth of from 12 ft to 17 ft bls. In addition, a sandy silt layer about 3-ft thick was also found between the depths of 24 ft to 27 ft bls in the west boring (Techna Corp. 1990).

The upper clay unit found in each of the three boreholes was generally underlain by a sequence(s) of wet sand. The sand sequence was reportedly interbedded with stiff, blue clay at all three locations. Wet sand and gravel were logged in both the northeast and south borings below a depth of approximately 90 ft bls (Techna Corp. 1990).

Two temporary ground-water monitoring wells were set in the northeast boring location and were screened at depths of 55 ft and 105 ft bls, respectively. One well was set at the west location at a depth of 56 ft bls, and two wells were installed south of the production building at respective depths of 50 ft and 93 ft bls (Techna Corp. 1990). All wells were fitted with 5-foot screens. The depths described above represent the locations of the bottom of each well screen. Monitoring wells were reportedly developed and allowed to return to static conditions following completion.

Techna reported the following conclusions:

1. The direction of ground-water flow was generally to the southeast.

2. The analyses of ground-water samples collected from the temporary monitoring wells did not indicate the presence of any VOCs.

3. The samples of the surficial soils were collected near each of the supply wells and analyzed for the presence of VOCs. No chlorinated solvents were detected in either soil sample (Techna Corp. 1990).

1.3.3.8 Michigan Department of Public Health Public Well Sampling - 1989

The Michigan Department of Public Health (MDPH) sampled seven residential wells located along the west side of Waterbury Road in early November 1989. These wells were the closest known to the Hi-Mill Manufacturing site. Ground-water samples collected from the wells were analyzed for metals and some VOCs. No VOCs were detected, and concentrations of metals were well within established limits (Techna Corp. 1990). The MDPH concluded that these seven wells showed no evidence of contamination.

1.3.3.9 Techna Corporation Remedial Investigation - 1990

Techna prepared and submitted a Remedial Investigation/Feasibility Study Work Plan, Site Safety Plan, and Quality Assurance Project Plan (QAPjP) to the USEPA as Revision 2 on October 26, 1989. This plan was subsequently amended following review by the USEPA and approved in January 1990.

The initial Remedial Investigation was conducted by Techna and its subcontractors and was funded by Hi-Mill Manufacturing Company in accordance with the Administrative Order of Consent, USEPA Docket Number V-W-88-C-127. Oversight of the Remedial Investigation field activities was provided by the USEPA and its designated contractors.

The Techna Remedial Investigation generally consisted of the extensive sampling and analysis of site soils as well as the installation of twenty-nine monitoring wells and six staff gauges (surface water). Of the twenty-nine monitoring wells, twenty-one were classified as "shallow", five were classified as "intermediate", and three as "deep". Staff gauges were installed in Target Pond and Waterbury Lake to monitor fluctuations in surface-water elevation. Logs of the stratigraphy encountered during drilling operations were recorded by Techna and utilized to interpret the site soils and geology. Monitoring wells were utilized to determine site ground-water quality and flow characteristics. Piezometers were used to supplement hydraulic data gathered from the monitoring wells, and staff gauges were necessary to develop an understanding of the interaction between adjacent surface water bodies and the ground-water flow system.

Techna established sampling grids around the facility in order to determine suitable locations for the collection of soil samples. Soil samples were analyzed for short list metals (SLM) including aluminum, chromium, copper, nickel, silver, and zinc. Techna developed isoconcentration maps to reflect the distribution of metals in both site soils and within the Target Pond/wetland area. Soils were also collected for analysis of the potential presence of VOCs in the vicinity of the former facility supply wells. Ground-water samples were collected from the shallow, intermediate, and deep monitoring wells for analyses of VOCs, metals, and standard water-quality parameters (e.g., pH).

A Baseline Risk Assessment was performed by Techna for the site and provided in the Remedial Investigation report submitted to the USEPA and MDNR.

As a result of its investigation, Techna developed several conclusions for the Remedial Investigation which may be summarized as follows:

1. Techna classified the subsurface soils and glacial drift into three flow systems: shallow, intermediate, and deep aquifers; these flow systems are separated by clay of varying thickness.

2. Techna concluded that the shallow aquifer was essentially representative of perched water and generally flowed away from the Hi-Mill Manufacturing plant toward Target Pond and Waterbury Lake.

3. The flow direction of the intermediate aquifer (as defined by Techna) was evaluated to be in a westerly direction away from the Target Pond/wetland area, while the ground-water flow direction within the deep aquifer was believed to be toward the southeast.

4. Techna detected metal concentrations in site soils and within the Target Pond/wetland area in excess of background levels at several locations.

5. VOCs such as TCE, 1,2-DCE, methylene chloride (ME), acetone, and toluene were detected in soils at several locations in the vicinity of the former water supply wells (which also happen to be near either existing or former aboveground storage tanks).

6. Techna postulated that overflows from the former lagoon area may have resulted in the transport of metals into the Target Pond/wetland area, and infiltration through the lagoons may have carried metals into the shallow ground-water flow system.

7. The shallow ground-water system is suspected to have transported dissolved metals and VOCs (Techna Corp. 1990).

8. Techna concluded that "due to the obvious dearth of both the diversity and the numbers of individuals per species represented, the risks associated with the heavy metal contaminants are probably minimal" (Techna Corp. 1990). No

conclusions were presented with regard to the existence of VOCs around the site building.

A draft version of the Techna Remedial Investigation report was submitted to the USEPA in June 1990 for review. Agency officials rejected the Techna document due to the fact that the document contained deficiencies so extensive that the integrity of the Remedial Investigation was questioned (USEPA, 1990).

1.3.3.10 Geraghty & Miller, Inc. Remedial Investigation - 1990 to 1992

Geraghty & Miller was retained to perform a review of the Techna Remedial Investigation report and data and to submit its findings to the USEPA and MDNR officials in the form of a Technical Memorandum. The primary objectives of the Technical Memorandum were:

1. To assess the conclusions and technical adequacy of the Techna investigation and to identify potential data gaps.

2. To recommend any additional data collection which may be necessary to complete the Remedial Investigation and Risk Assessment.

Following finalization of the Technical Memorandum, a Phase II Hydrogeologic Investigation Work Plan, Sampling Plan, and QAPjP package was prepared to address the additional work items needed to complete the Remedial Investigation. This document, representing the fourth revision of the Remedial Investigation, was submitted to the USEPA on September 24, 1991, and following final amendments by agency officials, was approved by the USEPA in October 1991. Some modifications to the original scope of work were made during the course of the investigation as conditions warranted. Approval was sought by USEPA and MDNR officials whenever possible.

The Geraghty & Miller Phase II investigation consisted of the following primary elements:

1. The installation of fifteen shallow piezometers in the upper perched aquifer.

2. The advance of four vertical profiles through the sand zone referred to by Techna as the "intermediate aquifer."

3. The installation of one additional monitoring well at a location and depth determined by vertical-profile sampling and analysis.

4. The drilling and sampling of 4-foot to 15-foot deep soil borings; two near each of the tank areas at the northeast and southwest corners of the building. Soil samples were analyzed for VOC content.

5. The completion of sixteen hand-auger borings (HABs) around the Hi-Mill Manufacturing plant. Another thirty-three hand-auger borings were also completed in the M-59 median. Ground-water samples were extracted from all hand-auger borings and analyzed with a portable gas chromatograph (GC) for VOC content.

6. The additional collection of ground-water elevations, ground-water chemistry data, and soil chemistry data for further delineation of the distribution of chemical species in and around the site.

7. A proposed Risk Assessment (RA) (concurrent with USEPA) to reassess potential risks to the environment and human health and safety, which was later deleted.

8. An Ecological Assessment and Inventory of the Target Pond/wetland area to determine the potential impact of metals on local ecosystems.

9. A complete revision of the Remedial Investigation report performed by Techna including all new data collected during the Phase II investigation, and a corresponding reassessment of all conclusions for the Remedial Investigation, Risk Assessment, and Ecological Assessment.

During the Phase II investigation, Geraghty & Miller identified several potential sources of VOC impacts to the site ground water and soils. These included the accidental release of approximately 250 gallons of TCE-based degreaser between 1978 and 1980; the former and existing above-ground degreaser storage tanks located at the northeast and southwest ends of the plant; the degreasing units and associated piping; and accidental spillage of degreaser outside of the plant affiliated with the servicing of the above-ground storage tanks.

Potential sources of metals found in the site soil, ground water, and adjoining surface water bodies (i.e., Target Pond and Waterbury Lake) included the wastewater lagoons formerly located at the rear of the plant; waste-acid solutions previously stored within concrete underground storage tanks; and fragments and chips of metal associated with Hi-Mill's manufacturing processes.

Potential off-site sources identified during the Phase II investigation included the adjacent Numatics facility located northeast of Hi-Mill, and a former service station which was previously located in the existing M-59 median area.

The preponderance of impacted ground water was found within the upper shallow "discontinuous" flow system, while the intermediate and deep flow systems underlying the site were found to be largely non-impacted. Shallow site soils immediately adjacent to the plant were found to be impacted with a variety of metals and VOCs. Vinyl chloride gas was encountered during drilling activities conducted at the northeast end of the plant.

While no impacts to the surface water of Target Pond were evident during the Ecological Assessment and Inventory, the bottom sediments of Target Pond were found to have been impacted by a variety of metals from either former activities at the Hi-Mill facility, and/or past or current activities at the adjacent Numatics facility.

Final approval of the Remedial Investigation Report was granted on February 5, 1993.

1.4 REPORT ORGANIZATION

This FS report has been organized into six sections. A brief description of each section is presented below:

Section 1.0 Introduction. This section describes the purpose of the report, provides a description of the site, and outlines the report organization.

Section 2.0 Summary of Site Conditions. This section summarizes the physical characteristics of the site, the nature and extent of the problem, the results of the risk assessment prepared by the USEPA, and the remedial action objectives developed for the FS.

Section 3.0 Screening of Remedial Action Alternatives. This section describes the screening criteria used to screen remedial technologies, the potential remedial action technologies which have been developed for the Hi-Mill site, and evaluates the potential remedial action technologies.

Section 4.0 Description of Potential Remedial Action Alternatives. This section presents each of the three primary alternatives to be evaluated as part of the FS. The three alternatives include a no action alternative, an institutional control alternative, and an active treatment alternative.

Section 5.0 Evaluation of Remedial Action Alternatives. This section utilizes the nine criteria described previously to evaluate each of the remedial action alternatives discussed in Section 4.0.

Section 6.0 Comparison of Alternatives. This section presents a comparison of each of the remedial action alternatives developed for the FS.

2.0 SUMMARY OF SITE CONDITIONS

This section presents a discussion of the site physical and chemical characteristics, as well as a discussion of the results of the USEPA-prepared risk assessment and the remedial action objectives developed for the FS.

2.1 PHYSICAL CHARACTERISTICS

A physical description of the site topography, climate, surface water, geology, hydrogeology, and ecology are presented in the following subsections. This section has been summarized from data and results originally presented in the final Remedial Investigation Report prepared by Geraghty & Miller (Geraghty & Miller, Inc. 1993).

2.1.1 General Surface Features

The surface topography and physical features of the Hi-Mill site are presented on Figure 2. The Hi-Mill facility occupies a gently (less than 2 percent) sloping area ranging in elevation from approximately 999 ft above mean sea level (msl) at Waterbury Lake to 1,011 ft msl south of the plant. There are several irregularly shaped upland areas ranging in elevation from 1,034 ft msl northeast of the site to 1,029 ft msl northwest of the site. Numerous shallow, closed depressions exist within the area and during periods of high rainfall and/or snowmelt may contain water. The topography of the area enveloping Hi-Mill is controlled by past-glacial and/or post-glacial processes.

Several surface water bodies are present in the area. These include Target Pond, Waterbury Lake, and the Alderman Lake (Figure 1). Target Pond is located approximately 100 to 200 ft east of Hi-Mill and is a shallow surface water body and marshy area occupying a shallow depression in the ground surface. Waterbury Lake and the [illegible] Arm of Waterbury Lake are separated by a small levee and are located approximately [illegible] 900 ft south of the plant building. Alderman Lake, located approximately 1,000 ft [illegible] of the Hi-Mill site, receives drainage from the storm sewer located in the M-59 med[illegible] roadway via a shallow creek which accepts outfall from the storm sewer system.

The Hi-Mill plant itself consists of an approximately 50,[illegible] square foot structure that is used for manufacturing, raw material storage and preparation, [illegible] product storage, and administration. No active underground storage tanks (USTs) are present on the site; however, a former fuel oil UST has been abandoned in place below the pre[illegible] area on the north side of the building. Presently, a single 1,000-gallon abovegroun[illegible] tank located on the southwest end of the building supplies degreasing fluid to two degr[illegible] located inside the plant via aboveground pipes. An additional aboveground storage [illegible] formerly located at the northeast end of the plant until it was removed to accommodate [illegible] expansion activities. The remainder of the Hi-Mill property consists of an approximately [illegible],000-square foot area including two paved parking areas and unpaved vegetated areas. The property is surrounded by a chain-link fence. A raised septic field located to the southwest of the plant accepts sanitary waste water from the facility. Figure 4 presents the principal site physical features discussed above.

The Hi-Mill site is bounded on the northwest by M-59, and generally on all other sides by the Highland State Recreation Area which is owned and operated by the MDNR. Property located northwest of the facility on the other side of M-59 is also part of the Highland State Recreation Area. A manufacturing facility owned by Numatics is located approximately 800 ft northeast of Hi-Mill. Several residences exist approximately 2,000 ft [illegible] of the site along Waterbury Road, with two properties adjoining the east shore of T[illegible] Pond.

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Prior to the expansion of M-59 from a two-lane road to a four-lane limited-access divided highway and the establishment of the Highland Recreation Area, a private residence, an airfield, and a former gasoline service station existed adjacent to the Hi-Mill site. The former gas station, purchased by Hi-Mill in 1946, was located approximately 150 ft northwest of the production facility. Hi-Mill Manufacturing used the structure for tool storage until the State of Michigan exchanged the presently paved parking area at the south end of the plant for the former gas station property in 1981. The private residences located north of the site and the airfield located south of the site were both incorporated into the Highland State Recreation Area.

2.1.2 Climate

The Hi-Mill site is located within a temperate climate zone with average monthly temperatures ranging (over the period 1987 through 1990) from approximately 25.9 degrees Fahrenheit (F.) in February up to 74.3 degrees F. in July (Geraghty & Miller, Inc. 1993). Overall, the area received an average of approximately 33 inches of precipitation annually over the same period, with the highest volume of precipitation occurring most commonly in June or July, and the driest months occurring at the beginning of the year in January or February (Geraghty & Miller, Inc. 1993). Climatological data presented herein was derived from the Remedial Investigation Report (Geraghty & Miller, Inc. 1993) in which data was presented that was obtained from the National Oceanic and Atmospheric Administration (NOAA) for the years 1987 through 1991.

2.1.3 Surface Water Hydrology

As discussed in the previous section, the Hi-Mill site is situated among several water bodies (Figure 1). Target Pond is adjacent to the east, Waterbury Lake and the North Arm to the south, and Alderman Lake to the northwest across M-59. These water bodies are surficially unconnected and lie within respective closed basins that do not possess surface-water drainage outlets.

Target Pond is rimmed by adjoining wetland areas and generally possesses a surface water area of between 8 to 10 acres at present, and a maximum depth of approximately 10 ft. Examinations of historical aerial photographs indicate that the size of these wetland areas change substantially depending upon the surface water level of the pond. In particularly dry years, Target Pond has been devoid of standing water and has been present only as a small wetland area.

The surface area of Waterbury Lake ranges from 35 to 40 acres and is rimmed by wetland areas. The maximum depth of Waterbury Lake is not precisely known, but it is substantially greater than that of Target Pond. The North Arm of Waterbury Lake is generally isolated surficially from the main portion of Waterbury Lake by a small levee as shown in Figure 2. Surface water level data suggest, however, that the two water bodies are hydraulically interconnected through the levee located between them.

Alderman Lake possesses approximately the same surface area as Waterbury Lake and is adjoined by a wetland area. An arm of Alderman Lake extends southeast of the lake to the northwest side of M-59 across from the North Arm of Waterbury Lake. It is this arm that accepts discharge via an outfall pipe from the storm sewer system located within M-59. No surficial connection between the North Arm and Alderman Lake has been confirmed, and no surface water exit point for the water in the North Arm has been located southeast of M-59.

Another arm of the Alderman wetland is located northeast of M-59 across from the north edge of Target Pond. Previous investigations have suggested that these water bodies may be connected surficially during high water periods via a culvert beneath the M-59 roadway. While a conduit is present near the northern edge of Target Pond, no outflow pipe has been discovered on the northeast side of M-59. It is possible that the conduit located near Target Pond connects into the M-59 storm sewer system.

Observations made during the remedial investigations indicate that Target Pond, Waterbury Lake, the North Arm, and Alderman Lake are generally ground-water discharge zones, and that any hydraulic connection between the surface water bodies appears to be only through the shallow ground-water flow system. No direct surface connection between the water bodies is evident. It is possible that during periods of heavy precipitation, the water bodies may recharge the shallow ground-water flow system. Please refer to the Remedial Investigation Report (Geraghty & Miller, Inc. 1993) for a more detailed discussion of this interaction.

2.1.4 Site Geology and Soils

Detailed descriptions of the site geology and soils obtained during the Phase I and II Remedial Investigations were used in the development of five geologic cross-sections (the locations of which are shown on Figure 5) presented in the final Remedial Investigation Report (Geraghty & Miller, Inc. 1993). These five cross-sections, A-A', B-B', C-C', D-D', and E-E', are presented here as Figures 6, 7, 8, 9, and 10, respectively.

The stratigraphic profiles shown in Figures 6, 7, 8, 9, and 10 include the following seven distinct geologic units: shallow soils and granular material, brown periglacial and/or post periglacial lacustrine deposits, blue periglacial and/or post periglacial lacustrine deposits, interglacial lacustrine deposits, glacial outwash deposits, and post-glacial fluvioglacial outwash.

A thin veneer of sandy topsoil occurs as the uppermost unit that overlies a thin horizon of fine sands, silts, and other various soil types. On the Hi-Mill property, this thin sandy soil is generally absent and has been replaced by a clayey fill material above an organic-rich topsoil or possibly peat.

A brown-gray variegated silty clay underlies the topsoil and appears to be rather uniform in thickness, generally occurs between 1000 and 1010 ft msl and, except for the rear of the facility, is generally continuous across the site. The brown clay pinches-out toward the south and west possibly due to erosion resulting from fluvial processes. The proportion of silt within the brown clay increases toward the west until the unit is more representative of a clayey silt. Furthermore, numerous thin sand and silt seams that appear to be the water-bearing material within this horizon, are interbedded within the brown clay. The occurrence of these sand and silt seams appears to decrease with increasing depth. The brown clay is absent at the southwest edge of the study area and is replaced by alternating deposits of sand, silt, and clay.

The brown clay is underlain by a stiff blue-gray clay that occurs between approximately 955 to 1000 ft msl except on the western edge of the study area. This gray clay contains numerous small sand and silt valves that are indicative of a lacustrine depositional environment. The gray clay thins toward the west and south and pinches out southeast of Target Pond.

Underlying the gray clay is a horizon of saturated outwash sands occurring from approximately 897 to 972 ft msl in the southwest, and 948 to 972 ft msl directly beneath the site. Except toward the north and southwest, this intermediate sand is approximately 28 to 30 ft thick across the site. The intermediate sand thins toward the north and thickens toward the south and west. The intermediate sand generally consists of medium to coarse-grained sand and fine gravel in the upper portions of the unit, and grades into a fine silty sand toward the south and west and a medium sand beneath the Hi-Mill facility.

The intermediate sand is underlain by a lower blue-gray clay layer which is composed of interglacial lacustrine clays similar to that of the upper gray clay horizon discussed previously. The lower gray clay pinches out toward the south and west and thickens to the east. Where the lower gray clay pinches out, the intermediate and deep sands (discussed later) merge into a single unit.

Below the lower gray clay horizon is a second layer of outwash sands similar to the intermediate sand unit. This deep sand was likely deposited prior to the deposition of the quiet, deep-water gray clay wedge. The deep sand unit merges with the intermediate sand to the southeast where the lower gray clay pinches out.

Little data are available below the deep sand horizon. However, a coarse sand, gravel, and boulder bed was encountered at a depth of approximately 90 ft bls during the installation of borings for Wells DW-1, DW-2, and DW-3 (Figure 11).

2.1.5 Site Hydrogeology

A total of 36 monitoring wells were installed by the MDNR, Techna, and Geraghty & Miller during previous investigations conducted at the Hi-Mill site at the locations shown on Figure 11. Fifteen piezometers were also installed on, and adjacent to, the Hi-Mill property, as were total of six staff gauges (Figure 11). Hydraulic data collected from these monitoring wells, piezometers, and staff gauges were used in conjunction with detailed geologic investigations of the site to delineate the site-specific hydrogeology and ground-water/surface-water interactions. Details of the collection and interpretation of these data were presented in the final Remedial Investigation Report prepared by Geraghty & Miller (Geraghty & Miller, Inc. 1993).

Subsurface ground-water flow at the site has been subdivided into five distinct hydrostratigraphic units. These include:

1. A shallow discontinuous flow system within the brown clay.
2. An aquitard represented by the upper gray clay.
3. The intermediate flow system within the intermediate outwash sands.
4. A lower aquitard represented by the lower gray clay.
5. The deep flow system within the deep outwash sands.

It should be noted that the lower aquitard (lower gray clay) does pinch out resulting in the hydraulic interconnection of the intermediate and deep flow systems to the southeast of the site. Presented in the following subsections are descriptions of each of the three principal zones of ground-water flow: the shallow, intermediate, and deep systems.

2.1.5.1 Shallow Discontinuous Flow System

Wells and piezometers completed within the shallow flow zone, and staff gauges were used to develop the shallow phreatic surface map presented on Figure 12. The shallow phreatic surface of this unit indicates that ground water flows radially away from a ground-water high located near the rear of the Hi-Mill plant toward Target Pond, Waterbury Lake, the North Arm of Waterbury Lake, and M-59. The ground-water high and general radial flow pattern of the shallow system is the result of local topography and recharge behind the Hi-Mill plant. The high level of recharge in this area is likely due to the presence of large paved areas located on and off-site which allow no recharge to the shallow system. In addition, water discharged into the plant septic field serves to increase the volume of recharge to the shallow flow system.

Several of the piezometers for which installation was attempted during the Phase II portion of the RI were found to be dry upon completion and were subsequently abandoned. Hand auger borings (HABs) were advanced for the purpose of installing these piezometers in the shallow flow zone. Holes were allowed to sit open for several hours and, in some cases overnight, to determine if the borings would fill with water. The presence of these "dry" locations may be explained by the absence of small silt and sand lenses capable of bearing water and periods of low precipitation that result in relatively minor recharge to the system. Furthermore, "dry" locations within the shallow flow system are indications that this regime is discontinuous with respect to continuity in ground-water flow.

An inspection of the shallow phreatic surface map on Figure 12 reveals that surface water elevations within the local surface water bodies are consistent with horizontal flow from the shallow discontinuous flow system into Target Pond and Waterbury Lake. Flow from the shallow system to the adjacent surface water bodies is expected to occur through small, relatively discontinuous lenses of silt and sand interbedded within the brown clay. Other sources of recharge to the surface water bodies include direct precipitation and runoff along small drainages located at the rear of the Hi-Mill facility. Comparisons of surface-water elevation data from Target Pond and the shallow system ground-water elevations indicate that Target Pond is a zone of discharge from the shallow flow system. Vertical communication between Target Pond and the intermediate flow system (discussed in Section 2.1.5.2) is expected to be minimal as the vertical hydraulic conductivities of the underlying upper gray clay are minimal. It is possible, however, that a series of very heavy precipitation events could raise the water level in Target Pond to an elevation which could allow recharge to the shallow system.

Examinations of water elevation data collected from the interbedded brown clay unit, coupled with available water quality and geologic data, would suggest that sufficient lateral and vertical interconnection of water-bearing sediments does exist to define the interbedded brown clay unit as a whole, as a more or less contiguous flow system. Horizontal hydraulic conductivities of this unit range from 1.53×10^{-5} centimeters/second (cm/sec) to 2.25×10^{-3} cm/sec (Geraghty & Miller, Inc. 1993). The bulk of the permeability present is attributable to the lenses of silt and sand interbedded within the brown clay. Analogously, the brown clay may be considered equivalent to a fractured bedrock where flow takes place primarily within available conduits (in this case, sand and silt seams) that may be vertically or horizontally interconnected to a greater or lesser degree depending upon depositional history and location. The "matrix" of the system in this case would compare to portions of the shallow system chiefly comprised of brown clay which possesses little silt or sand. The "matrix" is not expected to possess significant permeability and, as such, is not responsible for transporting much of the flow occurring within the shallow flow system as a whole.

The upper gray clay is believed to represent the hydraulic "bottom" of the shallow flow system (i.e., an aquitard). This is evidenced by the comparatively low vertical hydraulic conductivities observed for this unit which range from 1.4 x 10^{-6} cm/sec to 1.39 x 10^{-7} cm/sec, with an overall mean vertical hydraulic conductivity of 4.4 x 10^{-7} cm/sec (Geraghty & Miller, Inc. 1993). The potential vertical leakance for the upper gray clay was calculated using the value of vertical hydraulic conductivity, vertical gradients, and the thickness of the unit. These calculations indicate that it would take approximately 139 years for water to move from the top of the aquitard to the bottom of the aquitard near Well IW-4A, and approximately 564 years near Well IW-5 (Figure 11).

2.1.5.2 Intermediate Flow System

Nine monitoring wells completed within the intermediate flow system were used to develop the potentiometric surface map presented on Figure 13. The approximate overall ground-water flow direction in the intermediate system is toward the west. Overall flow in the intermediate system is believed to be controlled by the gentle dip of the intermediate sand horizon which gradually thickens toward the west. The ultimate areas of recharge and discharge to the intermediate system are not specifically known; however, inspection of cross-section A-A'

(Figure 6) suggests the intermediate sands may approach land surface toward the east of the site and this may be the likely zone of recharge to the intermediate system.

No evidence of a hydraulic connection between the intermediate system and Target Pond is evident based upon comparisons made between the intermediate ground-water elevations and Cross-section B-B' (Figure 7). Pressures within the intermediate zone monitoring wells suggest that it is a confined flow system and that the overlying gray clay may be classified as an aquitard (Geraghty & Miller, Inc. 1993). The intermediate and shallow flow systems are representative of separate flow regimes. Evidence for very tenuous connection between the two units includes:

1. The separation in ground-water elevations between the shallow and intermediate zone wells.

2. The lithology of the intervening stiff, gray clay compared to the intermediate sands and shallow clayey silts and sands.

3. The vertical hydraulic conductivity of the upper gray clay is generally three to four orders of magnitude lower than of the shallow silts and sands, and the intermediate sand horizon.

4. The potentiometric pressures within wells completed in the intermediate zone are several feet above the top of the intermediate sand horizon and the top of the screened interval.

Therefore, the interconnection between the shallow and intermediate flow systems (both on the site and downgradient) is not expected to be significant.

2.1.5.3 Deep Flow System

Data from three monitoring wells completed within the deep flow zone were used in the development of the potentiometric surface depicted on Figure 14. Ground-water flow within the deep zone based upon these data is generally toward the southwest. It is uncertain, however, whether data collected from Wells DW-1 and DW-3 are actually representative of the deep flow zone. At DW-1, the clay separating the deep and intermediate systems was penetrated during drilling and was not sealed during well construction. Similarly, Monitoring Well DW-3 may not be screened within the deep sands; rather it may be screened within a discrete lens of clayey sand interbedded in the clay underlying what has been previously regarded as the deep zone as shown in Cross-section D-D' (Figure 9). Comparisons were made between water elevations in the deep wells and adjacent intermediate wells. These comparisons suggest that very little hydraulic head separation exists between well pairs IW-2/DW-1 and IW-3/DW-2. While these data alone do not decisively demonstrate that the intermediate and deep systems are, in fact, one contiguous hydrostratigraphic unit, this information taken in conjunction with lithologic data collected from site borings does suggest that hydraulic communication likely does exist between the two systems owing to the absence of the lower gray clay layer west of the site.

Thus, the data suggest that the intermediate and deep sand horizons may, in fact, be hydraulically interconnected, possibly in the area lying immediately west of the Hi-Mill site (see Cross-section A-A', Figure 6). The potentiometric surface map of the deep system is therefore presented for consistency but is not believed to accurately depict the distribution of hydraulic heads and flow directions within the deep sand unit. Actual ground-water elevations and flow directions are believed to be consistent with those of the intermediate flow system.

2.1.6 Ecology

Presented in this section is a summary of the ecology of the Hi-Mill site. The final Ecological Assessment and Inventory was presented in the final Remedial Investigation Report prepared by Geraghty & Miller (Geraghty & Miller, Inc. 1993).

Analyses of the surface water in Target Pond indicated that natural conditions in Target Pond are different than the background locations. Target Pond contained higher concentrations of the following ions than background: Al, Ca, Fe, Mg, Mn, K, and Na (Geraghty & Miller, Inc. 1993). It is unlikely that activities at Hi-Mill produced these differences since none of the compounds listed above can be readily associated with the manufacturing process except for aluminum. These differences probably reflect different land use or soils within the respective watersheds or occur naturally in native soils. The levels of copper, nickel, and silver were above MDNR Rule 57(2) guidelines. However, the difference in the maximum copper concentrations in Target Pond and the background pond was less than the analytical precision of the laboratory, and the maximum concentration of nickel in Target Pond was the result of an undetermined bias in the analyses of the short list inorganics (Geraghty & Miller, Inc. 1993).

The detection of dissolved inorganic constituents in the waters of Target Pond may be due, in part, to former processing activities at Hi-Mill. However, an inspection of several MDNR reports suggests that the nearby Numatics facility, located about 800 ft northeast of Hi-Mill, may also act as a potential source of metals to Target Pond since process wastewater is discharged by Numatics into a septic drain field located behind the site building.

A terrestrial survey of the flora and fauna of Target Pond did not indicate the presence of adverse impacts related to activities at Hi-Mill (Geraghty & Miller, Inc. 1993). Dead trees were observed east of Hi-Mill and at several other locations in the area. Considering the distribution of these dead trees, it is unlikely that activities at Hi-Mill were responsible. The size and age of the dead trees at Hi-Mill were not different than the control group.

An aquatic survey did not indicate adverse impacts related to Hi-Mill. Target Pond supported a more numerous and taxonomically diverse assemblage of phytoplankton than the control site. The number of zooplankton in Target Pond was also larger and the taxonomic diversity similar to the control site. A diversity of benthic macroinvertebrates was recovered from Target Pond; however, the control site was devoid of these organisms.

Analyses of the bottom sediments of Target Pond indicated that Al, Ba, Cr, Cu, Mg, and Zn were statistically above background. The percentage of solids were higher in Target Pond and the pH and temperature lower. Like the dissolved metals, constituents found in the sediments of Target Pond may have their origins in activities at the Hi-Mill site or the adjacent Numatics facility.

The survival of Hyalella was significantly reduced relative to controls in only one sediment sample from Target Pond. This reduction was likely caused by lower pH or lower percentage solids. A statistically significant relationship existed between sediment toxicity and chromium levels; however, this relationship was not as strong as the pH and percentage solids of the sediments. For details of the Ecological Assessment and Inventory, refer to the final Remedial Investigation Report prepared by Geraghty & Miller (Geraghty & Miller, Inc. 1993).

2.2 NATURE AND EXTENT OF PROBLEM

Presented in this section is a summary discussion of the nature and extent of contamination and the contaminant fate and transport as delineated in the Final Remedial Investigation Report (Geraghty & Miller, Inc. 1993).

2.2.1 Nature and Extent of Contamination

This section presents a summary discussion of the nature and extent of contamination in the site and nearby soils, ground water, and surface water. The discussion was summarized from the Final Remedial Investigation Report issued on March 5, 1993 (Geraghty & Miller, Inc. 1993)

Sources of VOCs identified during the Phase I and Phase II Remedial Investigations include the aboveground degreaser storage tanks and related servicing operations (sources of TCE, and degradation products 1,2-DCE and vinyl chloride), parts degreasers and associated piping, the accidental release of TCE based degreaser during the construction of an addition to the plant building, and underground heating oil storage. Sources of inorganic compounds identified during remedial investigation activities include the abandoned wastewater recycling system, the evaporation lagoons formerly located at the rear of the facility, and discharges to Target Pond and the surrounding area resulting from direct releases and dispersal from the evaporation lagoons. Potential off-site sources of inorganic and organic compound contamination include practices at the adjacent Numatics facility, and USTs and service activities associated with a gasoline service station formerly located northwest of the site in the existing M-59 median.

The principal VOCs of concern identified in the site ground water and soils during the remedial investigations include TCE; 1,2-DCE; and vinyl chloride. Metals detected at levels above site background concentrations in the site ground water, soils, surface water, and pond sediments. Metals detected include aluminum (Al), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn).

Presented in the following subsections are discussions of the nature and extent of contamination with respect to each of the major site media identified including soils, ground water, surface water, and pond sediments.

2.2.1.1 Soils

During the Phase I investigation, an intensive program of soil sampling was conducted both off- and on-site in order to determine the chemical characteristics of site soils. Generally, soil samples were collected from two 20 foot by 40 foot grids, a 60 foot by 60 foot grid, off-grid locations and background locations. The location of these sampling grids is depicted on Figure 15.

The Phase II soils investigation consisted of the collection of soil samples during boring activities from the following locations: IW-6, IW-7, SB-1, SB-2, SB-3, and SB-4 (Figure 15). The results of soils analyses performed for both the Phase I and Phase II investigations for detected VOCs are shown on Figure 3. Similarly, those metals detected at concentrations in excess of the site defined background levels during the Phase I and Phase II investigations are summarized on Figure 15.

Thirteen VOCs were detected in soil samples collected during the Phase I and Phase II investigations. Five of the thirteen VOCs detected (i.e., 1,1,2,2-tetrachloroethane; 1,1,1-trichloroethane [TCA]; 1,1,2-TCA; ethylbenzene; and xylene) were detected at low-level estimated concentrations below the contract required detection limit (CRDL) ranging from 1 microgram/kilogram (μg/kg) to 3 μg/kg. Five additional VOCs (i.e., TCE; 1,2-DCE; tetrachloroethene; toluene; and chlorobenzene) were detected at concentrations greater than the CRDL and, in several cases, below the CRDL. TCE and its degradation products were detected at concentrations greater than the CRDL in both of the 20 foot by 40 foot sampling grids located near the former water supply wells (Figure 3).

TCE was detected in thirteen samples collected from the southwest grid and ranged in concentration from 2 μg/kg to 350 μg/kg. The highest concentrations of VOCs were in the brown-gray variegated silty clay. TCE was also detected in the northeast grid and ranged in concentration from 1 μg/kg to 41 μg/kg (with the exception of sample WV-01-3 and the resample of YX12-3), where the concentrations were similarly highest in the brown-gray variegated silty clay. TCE concentrations at WV-01-3 and YX12-3RE were detected at 57,000 μg/kg and 80 μg/kg, respectively. Soil Borings SB-1 and SB-2 were installed adjacent to the aboveground degreaser storage tank and contained TCE concentrations ranging from 13 μg/kg to 1600 μg/kg. Soil Borings SB-3 and SB-4, installed adjacent to the former aboveground degreaser storage tank on the north side of the building, contained detectable concentrations of toluene and TCE within the upper gray clay at a depth of about 15 ft bls. TCE was not detected within the intermediate or deep zones during soil sampling, with the exception of two samples collected from IW-6 at depths of 100 ft bls (2.8 μg/kg) and 115 ft bls (2.0 μg/kg). Both of these detections were estimated at levels below the CRDL and it is speculated that these samples may have been affected by cross-contamination.

The high concentration of TCE detected at soil sample location WV-01-3 (57,000 μg/kg) located in the northeast grid may be indicative of the presence of impacts beneath the Hi-Mill building itself. The damage of the product delivery line beneath an existing portion of the building undoubtedly resulted in the deposition of solvents beneath the facility. Detections of TCE at Borings SB-1 and SB-2 are likely related to servicing activities related to the aboveground degreaser storage tank, while those detected at Borings SB-3 and SB-4 may be related to a combination of the damaged product delivery line and servicing activities related to the aboveground storage tank formerly located at the north end of the building. Sources of degreaser likely account not only for the presence of TCE in site soils but also related degradation product 1,2-DCE which was often found to occur in conjunction with TCE. Several single detections of other organic compounds were also noted during the remedial investigations. These are possibly related to solvent impurities or different grades of industrial solvents.

Detections of toluene, ethylbenzene, and xylene (Figure 3) are probably related to the release of petroleum hydrocarbon-related products. Potential sources of these compounds include the use of cutting oils used during the processing of raw tubing, the presence of the service station formerly located in the M-59 median, and/or impurities within the degreaser supply. However, the precise source(s) of these compounds is somewhat uncertain since chlorinated solvents such as TCE do have the ability to mobilize heavier less mobile petroleum hydrocarbons.

A total of 13 semivolatile organic compounds (SVOCs) were also detected in soil samples collected from the background locations BG-1 through BG-5 and Grid Intersections I-4 and G-4 (Figure 17). Twelve of the 13 SVOCs detected (i.e., benzo(a) anthracene, benzo (b) fluoranthene, benzo (g,h,i) perylene, benzo (a) pyrene, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, chrysene, dibenzo(a,h) anthracene, di-n-octyl phthalate, indeo(1,2,3-cd) pyrene, phenanthrene, and pyrene) were detected at low-level estimated concentrations below the CRDL ranging from 0.049 mg/kg to 0.44 mg/kg. Two of the thirteen SVOCs (i.e., fluoranthene and toluene) were detected at a concentration greater than the CRDL. All SVOCs were detected at surface soil sample location BG-2 which is located near the former #2 fuel oil UST (Figure 16). Except for the three phthalate compounds, the detected compounds are indicative of fuel oil and are probably related to overfills of the UST.

2.2.1.2 Surface Water and Sediments

No analyses for VOCs were performed on either the surface water quality or sediments with Target Pond or Waterbury Lake. Samples collected from sediments within a background pond were analyzed and utilized to delineate background concentrations of metals. USEPA and MDNR criteria were used to determine background concentrations for surface water. Background samples of bottom sediments were also collected from Waterbury Lake during the Phase II investigation.

Sampling of the surface water in Target Pond during the remedial investigation revealed that the concentrations of Al, iron (Fe), magnesium (Mg), manganese (Mn), potassium (K), and sodium (Na), were all above background. Concentrations of Cr, Ni, and silver (Ag) were above MDNR Rule 57(2) guidelines.

Sediment samples collected from Target Pond indicated that concentrations of Al, barium (Ba), Cr, Cu, Mg, and Zn as well as percentage of solids and pH were all above site background levels.

Surface-water samples collected from Waterbury Lake revealed that only Ni and Ag were present at concentrations in excess of the water-quality criteria established by the USEPA and MDNR. Only Ag was actually higher than the results obtained from the background pond.

One sediment sample collected from Waterbury Lake (i.e., WL-1) demonstrated that the levels of Cr and Cu exceeded the sediment concentrations observed in the background pond during the Phase I Remedial Investigation. Waterbury Lake was used to establish sediment background levels for metals during the Phase II portion of the Remedial Investigation.

2.2.1.3 Ground Water

Ground-water samples were collected from wells completed within the shallow, intermediate, and deep flow zones during the remedial investigation. Eighteen shallow wells, nine intermediate wells, and three deep wells were sampled during the Phase II portion of the investigation. Analyses performed on these samples included the Short List Metals, and Target Compound List VOCs. Additionally, a total of forty-eight hand-auger borings were completed and samples collected from the open boreholes at various locations situated around the Hi-Mill Manufacturing building and adjacent M-59 median area. Samples collected from the hand-auger borings were analyzed for TCE, 1,1-DCE, 1,2-DCE, and vinyl chloride using a portable gas chromatograph (GC). Eight of the water samples collected from hand-auger borings located near the former service station were also analyzed for benzene, toluene, ethylbenzene, and xylene (BTEX) using the portable GC.

Only dissolved Al was found in concentrations in excess of MDNR background criteria during the Phase II portion of the remedial investigation. Dissolved Al concentrations ranged from 58.8 μg/L (SW-18) to 392 μg/L (SW-1) (Figure 16). Five of the six monitoring wells that contained above background concentrations of dissolved Al were found to have been screened in a clay horizon, suggesting that the possible source of Al may be naturally occurring.

VOC analyses of ground-water samples collected from the monitoring wells indicated the presence of fifteen different VOCs. Four of these fifteen compounds (acetone, methylene chloride, 2-butanone, and chloroform) were probably the result of laboratory or field cross-contamination. Nine of the fifteen compounds (TCE; 1,1-DCA; 1,2-DCE; 1,1,1-TCA; vinyl chloride; benzene; toluene; ethylbenzene; and xylene) detected were found to likely be the result of impacts to the shallow site ground water. The remaining compounds (4-methyl-2-pentanone, and bromodichloromethane) occur at a concentration of 1 μg/L and are likely laboratory artifacts. No impacts related to the presence of VOCs were noted in any of the ground-water samples collected from either the intermediate or deep flow systems. Four vertical profiles of the intermediate flow system failed to reveal the presence of any VOCs based upon the analysis of discretely collected ground water samples analyzed with the portable GC.

VOCs detected during the Phase II ground-water sampling of monitoring wells completed in the shallow flow zone, which were not related to laboratory or field contamination include TCE; 1,2-DCE; 1,1-dichloroethane; 1,1,1-TCA; vinyl chloride; and toluene. Figure 3 presents the results of all VOC detections in the monitoring wells during the Phase II portion of the remedial investigation.

During the hand-auger boring investigation conducted around the Hi-Mill facility and along the M-59 roadway, TCE, 1,2-DCE, vinyl chloride, and BTEX were all detected in varying concentrations in the shallow ground water flow system. The locations of all hand-auger borings are presented in Figure 18. Figures 19, 20, 21, and 22 present the distribution of TCE, 1,2-DCE, vinyl chloride, and BTEX as delineated during the hand-auger boring investigation. The highest concentrations of TCE, 1,2-DCE, and vinyl chloride detected during the hand-auger boring investigation were 55,000 μg/L (SBM-15), 3,500 μg/L (HAB-8), and 436 μg/L (HAB-6), respectively. The highest levels of BTEX compounds were detected near the former service station location at SBM-24 (Figure 22). With the exception of the BTEX compounds, the presence of TCE and its related degradation products is primarily attributed to the accidental release of 250 gallons of degreasing solvent between 1978 and 1980 at the location shown on Figure 2.

The highest detection of TCE in the shallow ground water system was 6,700 μg/L at Monitoring Well SW-1 (Figure 3). The highest detection of 1,2-DCE in the shallow ground water was also at SW-1 at a concentration of 1,400 μg/L (Figure 3). The only detection of vinyl chloride discovered in any of the shallow site monitoring wells was in Well SW-3 at the northeast end of the plant (39 μg/L). Additional detections of VOCs in the shallow site ground water as delineated from the sampling of the shallow monitoring wells are believed to be principally related to the accidental release of 250 gallons of degreaser in the late 1970s. The general lateral distribution of VOCs in the shallow site ground water has been delineated with a dashed line and is presented on Figure 3. Some of the detections in the shallow site ground water may also be due, in part, to servicing activities related to the existing and former aboveground degreaser storage tanks located at either end of the plant building (e.g., accidental spillage).

2.2.1.4 Summary

The findings of the Phase I and Phase II Remedial Investigations with regard to the distribution of soil, ground water, and surface water impacts at the Hi-Mill Manufacturing site may be summarized as follows:

1. Several potential sources of VOCs are present at the Hi-Mill Manufacturing site including the degreaser units, solvent storage tanks and associated piping. The most prominent source of VOCs is the past release of approximately 250 gallons of chlorinated solvents from the piping associated with the solvent storage tank located on the north side of the Hi-Mill Manufacturing production building. The release was caused by damage to the buried product delivery line during construction of a new addition between 1978 and 1980 (exact date unknown). The location of this tank and the piping is depicted on Figure 2.

2. The potential sources of metals occurring at the Hi-Mill Manufacturing site include the wastewater lagoons formerly located at the rear of the Hi-Mill

Manufacturing facility, waste-acid solutions stored within concrete USTs and fragments and chips of metal associated with Hi-Mill Manufacturing's manufacturing process. The location of the lagoons and concrete USTs are presented on Figure 2.

3. Several potential off-site sources have been identified in the region surrounding the Hi-Mill Manufacturing facility including Numatics and a former service station, which are located northeast and northwest of Hi-Mill Manufacturing, respectively. Dissolved gasoline compounds identified within the soil near the location of the former service station are likely the result of improper decommissioning and removal of USTs during the widening of M-59. If extensive automotive repair was conducted at the service station, then this former site could be a source of solvents used to clean parts. Numatics disposes of process wastewater through a septic field located adjacent to the Numatics production facility. Local shallow hydraulic gradients indicate that the water discharged to the septic field will flow toward Target Pond.

4) Soil samples collected during the Phase I and Phase II investigations were analyzed to determine the concentration of the SLM occurring within the soil. A large percentage of soil samples exceeded the background criteria established prior to the initiation of the Phase I Remedial Investigation. However, based on a review of the background and grid-sample descriptions, the background samples do not appear to representative of the soil conditions present on the site. Background samples of soils more representative of site soil types could be collected off-site at a non-impacted location.

5) Volatile organic analysis of soil samples collected during the Phase I and Phase II Remedial Investigation indicated that elevated levels of chlorinated solvents are present within the soil on the north side of the building near the former solvent storage area. Significantly lower concentrations of VOCs were detected in the soil on the southwest of the Hi-Mill Manufacturing facility and appeared to be limited to samples collected from the upper brown clay.

6) Surface water and sediment samples collected from Target Pond during the Phase I and Phase II investigations suggested that the Target Pond sediments may have been impacted by aluminum, chromium, copper, and zinc as a result of previous or current activities at the Hi-Mill Manufacturing and/or nearby Numatics facilities. The surface water of Target Pond, however, does not appear to have been significantly impacted.

7) The laboratory results of the Phase I ground-water sampling event indicated that only dissolved aluminum and nickel above the MDNR background criteria were present within the ground water at Hi-Mill Manufacturing. The resampling of the monitoring wells during the Phase II Remedial Investigation indicated that the nickel detected within the monitoring wells during Phase I was no longer present at levels above background. However, aluminum concentrations above background were detected during the Phase II Remedial Investigation ground-water sampling event.

8) Elevated concentrations of VOCs were detected during the hand-auger boring investigation and both the Phase I and Phase II ground-water sampling. Phase I water sampling results indicated that the shallow saturated zone was impacted with chlorinated solvents. The highest VOC concentrations were detected on the

north and southwest sides of the Hi-Mill Manufacturing facility adjacent to the past and present solvent storage tanks. Phase II ground-water sampling results indicated that elevated levels of VOCs present on the north side of the facility had decreased significantly. However, VOC concentrations on the south west side of the facility increased significantly between the Phase I and Phase II sampling events. The hand-auger boring investigation conducted during the Phase II Remedial Investigation in and around M-59 delineated the extent of chlorinated solvents within the shallow saturated zone in the M-59 median area. The delineated plume is believed to have been caused by the accidental discharge of degreaser during the construction of Addition #4. The highest VOC concentrations detected during the hand-auger boring investigation were located within the median of M-59 and appeared to extend to a source located on the Hi-Mill Manufacturing facility corresponding to the site of the aforementioned spill. Benzene, toluene, ethylbenzene, and xylenes were detected near the location of the former service station. The detection of elevated BTEX within the M-59 median is probably the result of the reported improper decommissioning and removal of the USTs during the construction of M-59.

9) In general, the ground-water samples analyzed from Vertical Profiles VP-1, VP-2, VP-3, and IW-6, detected no VOCs by portable GC analysis, suggesting that no impacts to the intermediate flow system by organics have occurred. One exception was an 11 parts per billion (ppb) detection of TCE at the bottom of VP-1. However, two subsequent samplings and analyses of this interval failed to confirm the presence of VOCs.

10) Analysis of two soil samples collected from the intermediate zone on Boring IW-6 indicates low levels of VOCs. It is suspected, however, these detections may have been the result of cross contamination.

11) Vinyl chloride gas which was discovered below the water table during the drilling of Profile VP-1 may have been produced as a result of the exposure of dissolved vinyl chloride above the intermediate zone to the atmosphere or may have already been present in the gaseous state in the vadose zone.

2.2.2 Contaminant Fate and Transport

This section presents a discussion related to the fate and transport of VOCs and inorganic compounds as summarized from the final Remedial Investigation Report issued on March 5, 1993 prepared by Geraghty & Miller. This section has been subdivided, for convenience, to present the potential fate and transport of contaminants through each of the major media of interest: ground water, soil, surface water and air.

2.2.2.1 Ground Water

Based on the shallow aquifer ground-water flow direction and the distribution of TCE, 1,2-DCE, and vinyl chloride detections, dissolved VOCs appear to be migrating northwest within the surficial discontinuous shallow ground water flow regime, toward the M-59 roadway and away from a source located on the Hi-Mill site. Furthermore, based on the information related to the solvent release discussed previously, the most likely source of dissolved TCE, 1,2-DCE and vinyl chloride within the shallow system is the occurrence of degreasing solvents released beneath the existing plant building as a result of the accidental damage to a product delivery line between 1978 and 1980 during the construction of an addition to the building. The northwesterly migration of VOCs continues until the dissolved constituents encounter the utility trench within the median of M-59. The coarse-grained backfill of the utility trench appears to channel the flow of the shallow ground water and dissolved VOCs toward the southwest. The preferential flow pathway along the M-59 median is shown by several low VOC detections and several non-detections north of the utility trench and M-59 at SBM-27, SBM-22, SBM-26, SBM-7, and SBM-12 (Figure 19).

VOCs detected on the south side of the Hi-Mill plant at HAB-6 and HAB-7 (Figure 19) may represent an older biodegraded release as shown by the greater concentrations of 1,2-DCE and vinyl chloride with respect to the concentration of TCE. Furthermore, HAB-6 is located within the nearly flat mound of shallow ground water located at the rear of the facility. The shallow ground water and VOCs identified near HAB-6 will migrate slowly toward the northeast.

BTEX detected in the shallow system near the former location of a gasoline service station in the existing M-59 median were likely the result of activities at the service station. These constituents are likely to move in the same direction as the chlorinated solvents identified previously.

2.2.2.2 Soils

Transport and migration of inorganic and organic compounds in unsaturated horizons of the shallow site soil may be accomplished as the result of the action of wind, surface water, human, or animal activities. Critical properties which can control the migration of inorganics in the unsaturated soil include the cation exchange potential, soil type; pH conditions, the oxidation state of metals, and whether or not the cation has been complexed with other anions such as chlorine. The pH conditions of the soil could have been affected by the dispersal of chromic acid washes containing a variety of metals species. The presence of acidic compounds could facilitate the transport of inorganic species downward through the vadose zone and into the zone of saturation. Migration of inorganics may also be enhanced as the result of downward percolating waters derived from precipitation events, as well as the chemistry of those waters. Large volumes of released metal-containing wastewaters may have also temporarily created a narrow zone of saturation in the vadose zone, thereby recharging the shallow site ground water with a wide range of metallic species. Metals left behind in the vadose zone are not expected to be subjected to significant further remobilization. Human contact with affected soil is considered to be the principal transport mechanism of concern. The erosion and transport of inorganics to different portions of the vadose zone via surface runoff and wind are also possible mechanisms of transport.

The primary physical characteristics influencing the transport of VOCs through the vadose zone are organic compound solubility, the vapor pressure, and the biodegradation of organics to form other compounds possessing different physical characteristics thus influencing their mobility. The major mechanisms of transport of organics in the vadose zone include the downward migration due to the percolation of infiltrating waters and incidental human contact and exposure. Soil gas migration may also play a part in the migration of organics; however, the available data do not suggest the clear presence of soil gas in the site vadose zone. The biodegradation of TCE to 1,2-DCE and then vinyl chloride can affect the transport of soil VOCs since the degradation products of TCE can have vastly different chemical properties (e.g., vinyl chloride's high vapor pressure).

2.2.2.3 Surface Water

The surface water bodies located adjacent to the site do not appear to have any surficial form of drainage. Target Pond is a likely recipient of metals-impacted water via overflow from the former wastewater lagoons and a drainage ditch located at the rear of the facility. Surface runoff following precipitation events may also play a role in transporting impacted materials into the pond. The most likely mode of transport from surface-water receptors to other surface water bodies would be via the shallow ground-water flow system. This form of "trans-media" migration will be discussed in greater detail in Section 2.2.2.5.

2.2.2.4 Air

Migration of compounds via the atmosphere is only feasible if organic compounds possessing adequate chemical properties to permit volatilization are exposed to the atmosphere. Dust particles of metal-impacted soils may be picked up and transported by winds; however, this is not considered to be a significant factor in compound transport since the site is either well vegetated or paved. Soil gas may also be important in the transport of VOCs through the atmosphere. Some form of human disturbance of the shallow site soils and/or ground water seems necessary, however, in order to facilitate the release of soil gas. This would be a form of "trans-media" migration which will be discussed in the following section.

2.2.2.5 Trans-media Migration

Trans-media migration of inorganics and organics from the vadose zone is expected to include transport of contaminants to the shallow site ground water via the percolation of infiltrating waters; surficial erosion of metal or VOC-affected soils by surface runoff into adjacent surface water bodies; disturbance of the site soils resulting in the release of soil gas to the atmosphere; the transport of organics into the site ground water via soil gas migration through the vadose zone; the transport of impacted soils to surface water bodies followed by the further migration of these subsequently impacted waters through the shallow ground-water flow system; and incidental human and/or animal contact or interference.

The mechanisms of trans-media migration of inorganics and VOCs from the site surface water include discharge to the shallow ground-water flow regime; discharge to other surface water bodies via the shallow ground water flow system; and incidental human and/or animal contact or interference.

Trans-media migration of inorganics and organics from the shallow ground-water flow system include the discharge of impacted ground water to local surface water bodies; the release of soil gas to the vadose zone; the release of gas to the atmosphere following some induced disturbance; and incidental human and/or animal contact or interference. The shallow site ground water is not considered a viable source of drinking water, thus, limiting the possibility of migration of impacted waters to human receptors.

2.2.2.6 Summary

The findings of the Phase I and II remedial investigations with regard to the fate and transport of impacted soils, ground water, and surface water may be summarized as follows:

1. Metals were chiefly introduced into the ground-water flow system and adjacent Target Pond by the discharge of water containing diluted acid-brightening solution laden with metals to the two former collection lagoons.

2. Metals were deposited in the site soils by the discharge of waste process water and those which did not remain in solution were fixed within the shallow site soils.

3. Inorganics discharged to Target Pond were deposited within the bottom organic sediments where they became fixed due to changes in solubility and the organic carbon content of the sediments.

4. Dissolved inorganics will generally move in the same direction as shallow ground-water flow.

5. Organics discharged by the accidental release of 250 gallons of TCE-based degreaser were introduced into the site vadose zone and shallow ground water. Residual ganglia were likely left behind following the spill but are not subject to further leaching due to the prevention of infiltration over this area by the completion of Addition #4. Organics reaching the shallow water table dissolved and the lateral extent of these constituents has been determined using a combination of hand-auger borings and GC analysis of water samples. Based upon the concentrations of TCE observed during the HAB investigation, and the nature of this spill, it is possible that DNAPL is present beneath or adjacent to the site building in the form of either pools or small lenses, or more likely, as trapped residual ganglia. This possibility should be taken into account when planning remedial alternatives, and care should be exercised to avoid directly contacting or intersecting potential free-product during further investigation.

6. Organic compounds spilled around former and existing tank areas were at least partially volatilized at the surface. While some residual was left in the unsaturated soils, infiltrating waters were the probable mechanism for dissolution and transport to the shallow ground-water flow system.

7. The detections of organic compounds found in site ground water may be moving toward Target Pond. No data are available on the organic concentrations of the Target Pond surface water or sediments.

8. Organics introduced into the shallow ground-water flow system are traveling in the general direction of ground-water flow; however, their transport has likely been retarded by the chemical properties of the compounds and the physical characteristics of the medium.

9. Vinyl chloride gas was encountered during the drilling of Vertical Profile VP-1, below the water table at a depth between 10 ft to 15 ft bls. The gas may have developed when dissolved vinyl chloride in the ground water was exposed to the atmosphere. While no data are available which indicate the presence of soil gas in the vadose zone, this transport mechanism cannot be completely ruled out.

10. None of the data suggest that VOCs transported by ground water have been discharged to potential surface-water receptors located west of M-59. However, two soil samples collected from Boring IW-6 did indicate the presence of low levels of VOCs. These samples may have been cross contaminated. Except for the results obtained from IW-6, no other data suggest that the intermediate or deep flow zones have been affected by organics.

11. Inorganics at concentrations above background levels were detected in the intermediate aquifer at Well SW-18; however, this well is downgradient of the Numatics facility which is a suspected source of metals for both the ground-water and surface-water flow systems.

12. Inorganics above background were detected in Shallow Well SW-20 which is downgradient of Numatics, Inc. not Hi-Mill Manufacturing. Thus, the detections in this well are believed to be the result of migration of metals from Numatics toward Target Pond.

13. The only inorganics discovered at concentrations above background within the intermediate flow zone were found at boring IW-6 (i.e., copper). The cause of these elevated metals concentrations is unknown; however, downward migration seems unlikely due to the distribution of metals near the source areas. The reliability of the background soil-sample locations is in some question, however, and as such may not be wholly appropriate for all site conditions. The location corresponding to IW-6 may represent a natural zone of anomalous concentrations of these metals.

14. Currently, the principal method of migration and transport of metals fixed within subsurface soils is believed to be incidental human contact with shallow impacted material. Flora and fauna may also be subject to contact, especially in Target Pond.

15. Wind-blown erosion and transport of soils affected by either organic or inorganic compounds is anticipated to be a minor mechanism of migration. Organics occurring at or near the surface are believed to have volatilized and evaporated soon after deposition. In addition, much of the site is either vegetated or paved, thereby inhibiting such a phenomenon.

16. Compounds which are either currently entering or have entered Target Pond by ground-water baseflow, surficial runoff, or wind-blown erosion are not anticipated to travel to any other medium. There is, however, a possibility that some discharge from Target Pond may occur to a narrow portion of the shallow flow system between Target Pond and Waterbury Lake. However, several HABs advanced in this area were dry, and available ground-water data suggests that a "static" or "flat" water table may exist here if portions of the shallow system are

saturated. Target Pond appears to be underlain by relatively impermeable clays and is not believed to represent a source of recharge to any subsurface flow system. In addition, surface topography indicates that all runoff in the area of the pond is toward the waterbody, not away. Staff-gauge data from Target Pond and the wetland areas across M-59 suggest that surface flow is toward Target Pond and under the roadway in the form of surface runoff from the M-59 median diverted into drainage grates into a drain pipe which emerges at the entrance to Alderman wetland. The overall decrease in metals concentrations in Target Pond between the Phase I and II investigations could be due to either a large variability in concentrations in sediments from location to location; sediment deposition and resuspension; differences in laboratory analysis and improved QA/QC during Phase II; or some combination of the above.

17. Surface runoff may transport affected soils toward Target Pond, however, organics which were deposited initially in surface soils are believed to have largely volatilized.

2.3 SUMMARY OF USEPA BASELINE RISK ASSESSMENT

The baseline risk assessment (SEC Donohue 1992), prepared by SEC Donohue under contract to the USEPA, is by definition an analysis of the potential adverse effects to human health and the environment in the absence of any remedial actions (including institutional controls) to control or mitigate releases or exposures. Essentially this is an evaluation of the potential risk under the no-action remedial alternative. The baseline risk assessment is divided into two major parts, the human health evaluation and the environmental evaluation. This section is a summary of the results of the baseline risk assessment report.

As a result of past activities at the Hi-Mill facility, 38 possible chemicals of concern (COCs) were identified in samples of ground water, soil, surface water, or sediments. These COCs included 19 VOCs, 2 phthalates, and 17 inorganic constituents.

The Hi-Mill facility is an operating metal parts fabrication plant. The current exposure pathway evaluated at the site was a worker exposed to the surficial soils at the site over a 25-year working period. Risk levels for the worker exposure scenario were essentially at or below levels of acceptable exposure, and therefore were not at levels of concern.

Although there are no plans to shut down the facility, as a hypothetical reasonable maximum exposure (RME) scenario for the future, it was assumed that the site would be developed for residential housing. These houses were assumed to have private wells that were screened in the shallow aquifer at the point of maximum detected ground-water contamination, although the placement of these wells would be unlikely and would not be allowed under current MDPH regulations (SEC Donohue 1992).

Exposure pathways that were evaluated for these future hypothetical RME residents included: (1) ingestion, dermal contact, and inhalation of COCs from the shallow ground water; (2) ingestion of soils; (3) inhalation of fugitive dust; (4) ingestion of home-grown vegetables; (5) ingestion and dermal contact with surface waters in Target Pond; and (6) ingestion of sediments from Target Pond. Exposure to Target Pond surface waters and sediments resulted in insignificant levels of risk, as did fugitive dust exposure.

Soil exposure as a result of direct contact with the soils, and ingestion of vegetables grown in the soil resulted in excess lifetime cancer risk (ELCR) levels of 10^{-5} or less, and hazard indices less than one. These risk levels are below the 10^{-4} ELCR guideline and hazard index guideline. The risk levels indicate that the soils at the Hi-Mill site probably do not warrant remediation as a result of current or future hypothetical exposure pathways.

Future hypothetical use of the shallow ground water as a potable water supply resulted in ELCR levels of 4 x 10^{-3} or less, and hazard indices of 37 or less. These risk levels are based on all potable uses of ground water and not just drinking water exposure. COCs with individual cancer risks greater than 10^{-6} included arsenic, beryllium, bromodichloromethane, trichloroethene, and vinyl chloride. COCs with hazard quotients greater than one included antimony, 1,2-dichloroethene, and nitrate/nitrite. These eight COCs predominated the elevated risk levels that were calculated for the ground water. Two of the eight COCs (beryllium and bromodichloromethane) were only detected in one sample, at or near the detection limit. For this reason only the other six COCs were identified in the baseline risk assessment as chemicals of chief concern. All eight of the COCs will be evaluated in developing cleanup levels for this site.

The evaluation of potential environmental impacts focused primarily on Target Pond. Wetland vegetation is abundant along the edge of Target Pond and exhibits no visible signs of site-related stress. Toxicity tests of sediment samples from Target Pond showed only limited indications of toxicity. Elevated concentrations of some metals were detected in the sediments; however, no correlation could be made between the metals in the sediments and the limited toxicity seen. In addition to Target Pond, terrestrial resources and potentially sensitive species were evaluated at the site. There are no indications of adverse impacts to either the terrestrial resources or sensitive species as a result of past releases at the Hi-Mill site.

In summary, the only exposure pathway resulting in risks at a level of potential concern was future hypothetical potable use of the shallow ground water. The ground water exposure risks are based on the assumption that the shallow ground water will be utilized as a potable water supply in the foreseeable future. This exposure pathway was identified in the baseline risk assessment as an unlikely exposure scenario (SEC Donohue 1992). Other human exposure pathway and ecological exposures did not have identified risk levels of concern.

2.4 REMEDIAL ACTION OBJECTIVES

Presented in this section is a discussion of the development process used to establish specific remedial objectives for the remedial alternatives. Remedial action objectives have been established for ground water and soil, and are discussed separately for convenience. Remedial objectives have been classified into the following two categories:

1. Objectives which were established based upon the identification of applicable, or relevant and appropriate requirements (ARARs); and

2. Objectives established using the results of the site-specific risk-based analysis presented in the baseline risk assessment developed by the USEPA.

The remedial action objectives presented are intended to provide specific goals for protecting human health and the environment. The remedial action objectives developed are used to establish medium specific response actions.

Presented in the following subsections are discussions of the specific processes employed to develop the remedial action objectives for each medium of interest. The following components have been specified for each medium of interest:

1. The contaminants of interest;

2. The allowable exposure routes and receptors based upon the baseline risk assessment (including ARARs); and

3. An acceptable contaminant level or range of levels for each exposure route.

2.4.1 Identification of Potential ARARs

Section 121 (d)(2) of CERCLA as amended by SARA specifies that Superfund remedial actions must comply with Federal environmental laws and promulgated State standards, requirements, criteria, or limitations which are more stringent than Federal laws. These laws and requirements must be legally applicable to the constituents of concern (COC), or relevant and appropriate given the circumstances of the release. The applicable or relevant and appropriate requirements (ARARs) can be either chemical-specific, location-specific, or action-specific (see Appendix B for the site-specific ARARs listing).

Location-specific (e.g., construction in a flood plain, local zoning requirements, etc.) and action-specific (e.g., air or water discharge requirements) will vary from site to site and action to action. These ARARs will be complied with on an individual remedy-by-remedy basis.

The potential chemical-specific ARARs for the Hi-Mill site would include the federal Safe Drinking-Water (SDWA) standards [Maximum Contaminant Levels (MCLs)] or the Michigan Act 307 criteria for the ground water. There are currently no federal standards or criteria for soils. Michigan Act 307 identifies generic soil criteria or methodologies for calculating site-specific soil criteria.

Federal SDWA standards for the shallow aquifer are not applicable because there are no wells located in the shallow aquifer. Potable wells in the vicinity are all screened in the intermediate or deep aquifer. Therefore, a potable standard is inapplicable for the shallow aquifer. Michigan Act 307 has a three tiered system of cleanup guidelines. Type A criteria are based on background, Type B criteria are based on generic drinking-water exposure pathways, and Type C criteria are based on site-specific exposure pathways. Michigan Act 307 soil criteria are based on a similar three-tiered system.

The MCLs and Michigan Act 307 Type B criteria for the COCs identified in the baseline risk assessment are listed in Table 1. The ground-water values are based on potable use of the shallow aquifer. Michigan Type B criteria for the soils are based on direct contact exposure with the soils and protection of ground-water quality. Soil criteria for protection of ground water is based on multiplying the Type B ground-water criteria by 20, although actual leachability testing or other methods may be used to establish Type B criteria (Michigan Administrative Code, Rule R299.5711).

Applicable site-specific cleanup criteria for the Hi-Mill site would be the Type C criteria. Site-specific values for the Hi-Mill COCs (Type C criteria) will be calculated, as the risk-based cleanup levels, in following sections.

2.4.2 Risk-Based Cleanup Levels

Exposure to contaminants in the ground-water was identified as the only exposure pathway of concern in the baseline risk assessment. Contaminant residues in the soils were not identified as a concern for direct contact exposure pathways or indirect (uptake by garden vegetables). To address the possibility that the contaminants detected in the soils are acting as a continuing source of contaminants leaching to ground water, soil cleanup levels will be calculated for protection of ground-water quality.

In accordance with Michigan Act 307 guidelines, when site-specific conditions result in exposure pathways significantly different from the generic Type B criteria exposure pathways, site-specific criteria can be calculated. Type C cleanup levels for shallow ground water and soils will be discussed in the following sections.

Cleanup criteria will be calculated for those exposure pathways which resulted in an ELCR greater than 10^{-4} and a hazard index greater than unity (one). Potable ground-water exposure was the only exposure pathway that exceeded these risk guidelines. COCs which contributed significantly to the elevated risks identified in the baseline risk assessment were antimony, arsenic, beryllium, bromodichloromethane, 1,2-DCE, nitrate/nitrite, TCE, and vinyl chloride. These eight COCs had either ELCR greater than 10^{-6} or hazard quotients greater than one. These are the eight COCs for which cleanup levels will be identified. It should be noted that the concentrations of arsenic detected in the ground water were already below federal MCLs and that beryllium and bromodichloromethane were only detected in only one ground-water sample each; therefore, cleanup criteria for these three COCs should have minimal influence on the development of remedial alternatives.

Cleanup levels were developed for the five potential carcinogens (arsenic, beryllium, bromodichloromethane, trichloroethene, and vinyl chloride) using an ELCR of 10^{-6} as an acceptable risk level for each COC. Cleanup levels for the three non-carcinogenic COCs (antimony, 1,2-DCE, and nitrate/nitrite) were developed using a hazard index of one for each of the COCs. The cleanup criteria were not based on additive effects because the toxicity endpoints for the three COCs are different.

2.4.2.1 Ground-Water Cleanup Levels

There are no potable wells located in the shallow ground-water aquifer, either on-site or off-site in the direction of plume migration. All identified wells are screened in the intermediate or deep aquifer. For this reason, the Michigan Act 307 Type B criteria for ground-water are inapplicable. The most likely hypothetical future use of the shallow ground water, for both on-site and off-site locations, would be as a source of landscape irrigation water. Exposure would result from periodic dermal contact and incidental ingestion/inhalation exposure to the spray mists. Ground-water cleanup levels will be calculated as site-specific Act 307 Type C criteria for a non-potable exposure scenario.

The receptor population expected to be exposed to the irrigation waters most frequently would be a grounds keeper or maintenance person that would be responsible for irrigating the lawns or shrubs. Given the local climatic conditions, exposure is expected to be limited to an approximate four month period (mid-May to mid-September) when lawn watering might be necessary in Michigan. The following conservative assumptions were used in calculating the non-potable ground-water cleanup levels:

(1) body weight of 70-kg;
(2) incidental water ingestion rate of 5 mL/hour;
(3) exposed skin surface area of 9,350 cm^2 (hands, arms, neck, and face);
(4) exposure time of 1 hour per day;
(5) exposure frequency of 17 days per year (1 days per week for 17 weeks);
(6) exposure duration of 25 years.
(7) lifetime averaging period for possible carcinogens; and
(8) averaging period of 25 years for non-carcinogenic COCs.

The equation used to calculate the ground-water cleanup levels is listed in Table 2. Ground-water cleanup levels for the COCs are listed in Table 3.

2.4.2.2 Soil Cleanup Levels Based on Leachability

A number of COCs have migrated from the soils to the ground water in the past. Soil cleanup levels were developed to protect against the possibility of continued migration of COCs to the ground water. The goal of these soil cleanup levels is to protect the quality of the ground water.

The method used to determine these cleanup levels was the Summers model, as described in the document entitled, "Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples" (USEPA 1989). A brief description of the model equations and assumptions are presented in this section.

The Summers model is based on the assumption that rainfall infiltrating through the soil will result in the desorption of some of the contaminants sorbed to the soils, resulting in the migration of the dissolved contaminant to the ground water. The desorption mechanism is based on soil:water partition coefficients. Starting with the ground-water cleanup levels identified in the previous section it is possible to calculate a soil concentrations for each of the COCs using the following formula:

$$C_s = \frac{K_d[C_{gw}(Q_p + Q_A)]}{Q_p}$$

Where:

C_{gw} ground-water cleanup level (mg/L);

C_s soil cleanup level protective of ground water (mg/kg);

K_d distribution coefficient (L/Kg);

Q_A volumetric flow rate of ground water (ft^3/day); and

Q_p infiltration through the soil (ft^3/day).

Volumetric flow in the shallow aquifer can be calculated based on the velocity and aquifer dimensions using the following equation:

$$Q_A = Vhw$$

Where:

h thickness of the aquifer (ft);

w width of the site perpendicular to flow (ft); and

V velocity in the aquifer (ft/day).

A value of 0.047 ft/day was used for V based on the results of RI. A value of 200 ft was used as the width of site perpendicular to flow. This is an simplifying assumption as flow is actually radial beneath a portion of the site. A value of 6 ft was used as the thickness of the shallow aquifer. Inserting these values into the equation above results in a volumetric flow rate through the shallow aquifer (Q_A) of 56 ft^3/day.

For the Hi-Mill site an estimated value of 9 inches/year of infiltration resulting from rainfall was assumed to fall over the site area of 100,000 ft^2. Substituting these values and solving for Q_p:

$$Q_p = IA$$

$$= [(9 \text{ in/yr})(\text{ft}/12 \text{ in})(\text{yr}/365 \text{ days})](100{,}000 \text{ ft}^2)$$

$$= 205 \text{ ft}^3/\text{day}$$

Where:

A area of site (ft^2); and
I infiltration rate (ft/day).

In order to determine the concentrations of COCs that will be strongly sorbed by the soils, it is necessary to use the distribution coefficient for each constituent. As a simplifying assumption the sorption of the organic COCs to the soils is assumed to be a function of the partitioning to the organic matter in the soils. The distribution coefficient can be estimated using the following equation:

$$K_d = K_{oc}F_{oc}$$

Where:

F_{oc} fraction of organic carbon in soil; and

K_{oc} organic carbon partition coefficient.

The average organic carbon content of the soils at the site was estimated to be 1 percent. Literature values for the K_{oc} were used to calculate the distribution coefficients. For the inorganic COCs the distribution coefficients were based on empirical values from the literature, because partitioning of inorganics is a function of much more than sorption to organic carbon.

Using these equations and the parameters discussed the calculated soil cleanup levels are presented in Table 4. These soil concentrations would be protective of ground-water quality.

2.4.2.3 Summary of Risk-Based Cleanup Levels

The risk-based cleanup levels calculated for the Hi-Mill site are based on the results of the baseline risk assessment. Protection of ground-water quality for future use, both on-site and off-site, was the focus of the cleanup levels that were developed for both ground water and soils. Soils were not a direct contact concern; therefore, soil cleanup levels were calculated to ensure that soils concentrations would not result in future leaching of COCs to the ground water at concentrations of concern.

Ground-water and soil cleanup levels are presented in Tables 3 and 4. These risk-based cleanup levels are not absolute cleanup levels, but rather are goals which would be protective if achieved. Actual field conditions will vary during remedy implementation; therefore, flexibility in the cleanup levels is important. This flexibility can be achieved by providing that the overall goals with respect to the COCs are to remediate the site such that the hazard index and ELCR for the soil or ground water taken as a whole do not exceed one and 10^{-6}, respectively. For example, after soil remediation, confirmation samples are likely to be required. If these samples indicate that the overall risk from the COCs, either individually or in combination, are below the threshold values, the remediation should be considered complete.

2.4.3 Summary of Remedial Action Objectives

Ground water and soil, as a source of continued leaching to ground water, were identified as the exposure pathways of concern in the baseline risk assessment. Federal and State standards for the ground water are based on the assumption that the ground water would be used as a source of drinking water. At the Hi-Mill site, the shallow ground-water aquifer is not currently used as a source of potable or non-potable water. Given the characteristics of the aquifer and the availability of a better supply of water in the intermediate and deep aquifer, it is unlikely that the shallow aquifer will be used as a supply of drinking water in the foreseeable future. For this reason the SDWA standards and the generic Michigan Act 307 Type B criteria are not applicable or relevant and appropriate for the shallow aquifer.

Ground-water standards for the intermediate and deep aquifer are the SDWA MCLs and Michigan Act 307 Type B criteria. These generic ARARs for ground water as a potable water supply are listed in Table 5.

Risk-based cleanup levels for the shallow aquifer were developed for protection of the ground water as a source of irrigation water in the foreseeable future. The cleanup levels are protective of a worker exposed to the water by both dermal contact and ingestion of mists. The site-specific ground-water cleanup levels (Type C criteria) are summarized in Table 5.

Site-specific soil cleanup levels (Type C criteria) that would be protective of ground-water quality were developed using a partitioning-based unsaturated zone transport model. Cleanup levels calculated for the soils would be protective of ground water at the risk-based cleanup levels. Soil cleanup levels are summarized in Table 5.

These are the chemical-specific ARARs and risk-based cleanup levels that will factor into the development of remedial alternatives. Achievement of these ARARs and risk-based cleanup levels would result in future protection of human health and environment.

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

In this section of the feasibility study, a list of potentially applicable remedial technologies is identified that might be used to satisfy the remedial action objectives that were established in the preceding section of this report. The list of potentially applicable technologies is then reviewed through a screening process to identify the technologies that are applicable to the site conditions, can be effective in meeting the site-specific remedial action objectives and can provide a reasonable benefit for the costs expended.

3.1 PRESUMPTIVE REMEDY APPROACH

As a preliminary step in developing the remedial action alternatives for the Hi-Mill Manufacturing facility a targeted list of technologies that are considered to be potentially applicable was developed. The targeted list of remedial technologies was presented to the USEPA for review in the document entitled, *"Proposed Feasibility Study Scope of Work", Hi-Mill Superfund Site, Highland Michigan,"* which was prepared by Geraghty & Miller and submitted to the Agency in March 1993. Preparation of the targeted list of technologies was consistent with the presumptive remedy approach that has been adopted, after consultation with USEPA for the development and evaluation of remedial action alternatives for the Hi-Mill site. The use of the presumptive remedy approach is advised where either the physical site characteristics or the nature and extent of contamination, preclude the effectiveness of a large number of technologies that might otherwise be considered.

Procedures for technology screening described in the USEPA manual *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988) consist of a two-step screening process. The potentially applicable remedial technologies are to be first evaluated on the basis of technical implementability relative to site conditions. If considered technically implementable, the potential technology is further evaluated on the basis of its effectiveness, implementability and cost. This two-step screening procedure has been modified somewhat in the present study, due to the fact that the presumptive remedy approach is being utilized for the Hi-Mill site.

Technical implementability based on the site conditions was previously considered during development of the targeted list of potential remedial action technologies that was presented in the scope of work for the feasibility study. Consequently, the targeted list of technologies will not undergo the initial screening step, but will be screened immediately based on relative effectiveness, implementability and cost.

A summary of the physical site characteristics that limit the number of remedial action technologies that are potentially applicable to the Hi-Mill site is presented in the next section. Following this summary, a screening evaluation of the targeted list of potentially applicable remedial technologies is presented.

3.2 LIMITING SITE CONDITIONS

There are several physical characteristics at the Hi-Mill site that combine to limit the number of remedial technologies that are potentially applicable for remedial action at the site. These characteristics include: (1) low transmissivity (less than 50 gpd/ft) in the shallow ground-water flow system; (2) shallow ground-water elevations within the uppermost clay unit (brown clay) encountered at the site; and (3) the potential presence of residual solvent (related to historic damage to product delivery line) within the brown clay unit beneath the existing manufacturing building. The limiting effect of each of these site characteristics on the use of potential remedial technologies is discussed below.

The interpreted shallow flow system at the site consists of the brown clay and interbedded lenses of silt and sand that were observed in soil borings completed during the Phase I and Phase II remedial investigations. The brown clay unit, which is the uppermost clay unit encountered has a uniform thickness across the site and generally occurs at elevations between 1000 and 1010 ft msl. Water elevation data collected from the interbedded brown clay suggest that sufficient lateral and vertical interconnection exist to define the brown clay unit as a continuous flow system. This unit has been designated as the shallow flow system at the site. The results of ground-water sampling from shallow wells (wells completed within the interbedded brown clay) and hand-auger borings conducted during the Phase II investigation indicated the presence of VOCs, primarily TCE, that exceed the risk-based cleanup levels that have been established for the site (see Table 5). Based on the water quality results the shallow flow system has been targeted in the present study for evaluation of potential remedial action alternatives.

The use of conventional pump and treat technologies is expected to have limited effectiveness due to the low transmissivity in the brown clay unit. During the Phase I remedial investigations conducted by Techna, values for the horizontal hydraulic conductivity in the brown clay unit were determined from the results of baildown tests performed on shallow monitoring wells. The geometric mean of the measured values for hydraulic conductivity was 1.81×10^{-4} cm/sec. The measured horizontal hydraulic conductivity is likely representative of the sand and silt seams that are interbedded in the brown clay and are believed to be responsible for transporting the majority of the ground-water flow that occurs in the shallow system. The actual response of the shallow flow system to pumping would be dictated by the number of water-bearing lenses of sand and silt intercepted by the well, and the degree to which these lenses were connected laterally and vertically. In addition, the saturated thickness of the shallow flow system is very limited. Based on the Phase II water level measurements the saturated thickness of the brown clay unit across the site varies from five to seven feet. In situations where the saturated thickness of a water-bearing unit is limited, the capture zone of an individual recovery well cannot be increased simply by increasing the pumping rate. This is due to the fact that the added drawdown from increased pumping cannot exceed the total saturated thickness of the unit. At sites with low transmissivities, therefore, a large number of low capacity pumping wells would be required to effect capture/containment of a zone of affected ground water.

Another site characteristic that impacts the types of remedial technologies that can be considered for potential remedial action is the shallow depth to ground water. In particular, this influences the type of technologies that may be applicable for treatment of residual material in suspected former VOC source areas. Trichloroethylene was detected during the Phase I and II remedial investigations in soil samples collected from two suspected source areas at concentrations that exceed the risk-based cleanup levels for soils presented in Section 2.4.2.2. The soil cleanup levels have been established for the protection of ground water.

Concentrations of TCE exceeding the risk-based cleanup levels were detected in soil samples collected from the northeast grid and also from Soil Borings SB-1 and SB-2 located on the southwest side of the facility (see Figure 3 for locations). The TCE detected at borings SB-1 and SB-2 is believed to be associated with servicing activities at the aboveground solvent storage tank. The TCE found in soil samples from the northeast grid may be related to a combination of the damaged product delivery line and service activities related to the former aboveground solvent storage tank that was located in this area.

The depth to ground water measured at these locations during the Phase II investigations ranged from 1 to 2-1/2 ft below land surface. Under these conditions, the effectiveness of in-situ vacuum extraction technologies would be limited, unless depression of the water table was implemented in conjunction with the vacuum extraction technology.

The results of soil sampling conducted during the Phase I and Phase II remedial investigation indicate that impacts to the brown clay unit on the north side of the building that resulted from the damage to the product delivery line may extend beneath the building. Therefore, the use of in-situ remedial technologies would be required to address any residual VOCs that may be present in suspected former source areas beneath the building.

3.3 EVALUATION AND SCREENING OF TECHNOLOGIES

In order to meet the remedial action objectives that have been established for the Hi-Mill site (see Section 2.4) given the physical constraints imposed by the site conditions, the following targeted list of potentially applicable remedial technologies has been identified:

- Deed Restrictions
- Ground-Water Monitoring
- Soil Vapor Extraction
- Vacuum Enhanced Recovery
- Air Sparging/In-Situ Air Stripping

The list of technologies includes both active treatment and monitoring technologies. Based on the nature and extent of contamination at the site, as described earlier in Section 2.2, the overall goal of any active treatment program that might be implemented would be to contain and treat ground water that exceeds the risk-based clean-up objectives, treat residual VOC contamination present in the identified source areas, and control the vapor phase present in the vadose zone. The list of active treatment technologies was selected after consideration of each technology's ability to meet these goals either alone, or in combination with one or more of the other technologies. Each of the individual technologies will be evaluated in the following sections based on its effectiveness, implementability and cost.

Effectiveness, which is given primary importance in this technology evaluation process, is defined as the degree to which a technology can attain the remedial action objectives, ensure the protection of human health and the environment during its implementation, and be considered reliable and proven with respect to the contaminants and conditions at the site.

Implementability, which considers both technical and institutional implementability, is defined as the ability of a given technology to be compatible with the constituents and conditions at the site, the ability to obtain any necessary permits, the availability of treatment, storage, or disposal capacity, and the availability of required equipment and trained personnel.

The cost evaluation compares the relative capital and operation and maintenance cost associated with each given technology. Relative costs referenced in this section are estimated on the basis of engineering judgement, and each process is evaluated relative to the process options in the same technology type. These relative costs are presented as low, medium, or high.

3.3.1 Deed Restrictions

The use of deed restrictions would be an effective means of regulating and controlling future land use and property development at the Hi-Mill Manufacturing facility. The only unacceptable risk (i.e., based on acceptable risk ranges established by the USEPA) to public health identified in the baseline risk assessment for the Hi-Mill site results from the hypothetical, future on-site resident exposure scenario. The unacceptable risk under this scenario results primarily from the ingestion of ground water containing VOCs. The baseline risk assessment (SEC Donohue 1992) concluded that there are no unacceptable existing risks to workers associated with the current industrial use of the property. By placing deed restrictions on the property that would limit its future development to industrial use, the future hypothetical exposure scenario associated with the residential use of ground water would be eliminated.

The historical precedent of industrial land use at the Hi-Mill property would serve to strengthen the effectiveness of deed restrictions. The Hi-Mill Manufacturing Company has operated an industrial facility at this location on a continuous basis since 1946. Community development planning does not contemplate the conversion of existing industrial properties to residential use. The use of a deed restriction to limit site activities is readily implementable, offers long-term effectiveness, assists in meeting the remedial action objectives for the site, and is a low-cost technology. The use of deed restrictions will therefore be retained as an applicable technology for remedial action at the Hi-Mill site.

3.3.2 Ground-Water Monitoring

Periodic monitoring of the ground water at the Hi-Mill site would be an effective means of identifying changes in ground-water quality at the site. Ground-water monitoring is also used for assessing the overall effectiveness of any active remediation efforts and verification of when remedial action objectives are achieved. Although ground-water monitoring would require a long-term commitment, it would be relatively inexpensive and easy to implement. A ground-water monitoring program at the site would utilize the existing network of downgradient monitoring wells, as well as any additional wells to be installed, to periodically assess the ground-water quality. Based on its effectiveness in assessing ground-water quality, ease of implementation, and relatively low cost, ground-water monitoring will be retained as an applicable technology for remedial action at the Hi-Mill site.

3.3.3 Soil Vapor Extraction

Soil vapor extraction (SVE) is a treatment process that has been developed to remove VOCs from unsaturated zone soils. The process consists of applying a metered vacuum to a vapor extraction well(s) installed in the zone of VOC contamination, in order to induce an air flow through the subsurface soil. Ambient air can be drawn either directly from the ground surface, or through air inlet wells placed at or beyond the boundary of the contaminated zone. As the "clean" air is drawn through the VOC contaminated soil, it displaces the soil gas which is in a vapor phase equilibrium with any residual VOCs adsorbed onto the soil particles. The soil gas is drawn off by the air-extraction wells and the "clean" air reaches an equilibrium with the soil matrix. These gases are induced to migrate to the extraction well by an engineered, subsurface pressure gradient developed by a blower or vacuum pump system. As the process continues, the residue mass of VOCs in both the soil solids and pore water are gradually drawn off with the vapor phase as a result of concentration gradients. In addition to the direct physical removal of VOCs, secondary biological degradation processes are likely to be enhanced by the subsurface aeration that necessarily accompanies the SVE process. SVE systems are usually considered in applications where a significant mass of VOCs is present in the vadose zone, and leaching of this material is contributing to ground-water contamination.

A review of operating systems indicated that the soil characteristics at a particular site have a significant effect on the applicability of soil vapor extraction systems (Hutzler, Murphy et at. 1989). Air conductivity controls the rate at which air can be drawn from the soil by the applied vacuum. Grain size, moisture content, soil aggregation, and stratification are reported as the most important properties (Bennedsen, Scott et al. 1985). References in the available literature indicate that SVE is most effective in removing compounds with vapor pressures over 1.0 mm of mercury (Hg) and Henry's law constants greater than 0.01 (Pedersen 1991). The design of SVE systems is typically performed on an empirical basis, utilizing pilot test to establish the operating parameters (i.e., radius of influence, applied vacuum, air flow rates, etc.) for the full-scale system.

Effectiveness: The results of soil sampling conducted during the Phase I and Phase II Remedial Investigation (Geraghty & Miller, Inc. 1993) indicated that elevated levels of VOCs are present within the soil on the north side of the building near the former solvent storage area. The primary VOCs that were identified include TCE, 1,2-DCE and VC. The highest concentrations of VOCs in this area were detected in the brown/gray variegated silty clay (brown clay) which is the first clay unit encountered at the site. The brown clay contains interbedded layers of silt, sand and clayey silt which are inferred to represent the primary saturated zones comprising the shallow flow system. The base of the brown clay unit in the vicinity of the former solvent storage area is at an approximate elevation of 1000 feet msl.

During the Phase II remedial investigation static water levels were measured in the shallow monitoring wells on a monthly basis during the period from December 1991 to June 1992. Shallow ground-water elevations measured at Monitoring Well SW-3 (located near former solvent storage area on the northeast side of the facility) ranged from 1006.76 ft to 1008.01 ft msl. The ground surface elevation measured at Monitoring Well SW-3 was 1009.33 ft msl. This would correspond to an unsaturated thickness in the brown clay unit that varied roughly from 1 to 2-1/2 ft The shallow depth to ground water in this area would limit the effectiveness of an SVE system, even if a horizontal configuration were used. In order to enable air flow through the zone of residual contamination within the saturated soils below the water table, ground-water levels would have to be lowered.

A secondary source area of VOCs was identified during the Phase I and Phase II remedial investigations in the vicinity of the above-ground solvent storage tank that is located southwest of the manufacturing building. This area is characterized by Soil Borings SB-1 and

SB-2 (see Figure 3 for locations) which contained TCE concentrations ranging from 13 μg/kg to 1600 μg/kg. The highest concentrations of TCE detected from these boring locations were found within the brown clay unit at a depth of 7-1/2 ft bls which corresponds to an approximate elevation of 1003 ft msl.

The highest ground-water elevations measured during the Phase II remedial investigation were generally recorded during March 1992. The potentiometric surface map constructed from the March 1992 water level data is shown in Figure 12. Shallow ground-water elevations in the vicinity of the above-ground solvent storage tank were approximately 1009 ft msl during this period. As was the case for the primary VOC source area identified on the northeast side of the facility, partial dewatering of the brown clay unit would be necessary to improve the effectiveness of an SVE system.

Because of the water table conditions at the Hi-Mill site, SVE would not be an effective technology for treatment of residual soil contamination in VOC source areas. The use of SVE technology would only be applicable for site conditions in combination with technologies that could be used to depress the water table in the brown clay unit encountered at the site.

Implementability: The construction methods for soil vapor extraction systems are conventional in nature and well documented. Installation of vapor extraction wells and/or horizontal vent lines at the Hi-Mill site, however, might be complicated by the proximity to building foundations and possible interferences from underground utilities.

Equipment and services required to install the basic vacuum recovery system would be available locally. However, specialized equipment would be required if treatment of the air emissions from the SVE system were necessary. This equipment (e.g., vapor-phase carbon, catalytic oxidation, etc.) is available from several vendors. In the case of carbon treatment, unless regenerated onsite, the spent activated carbon would require special handling and transportation offsite for regeneration.

Once installed, the performance of an SVE system can be monitored using several methods. SVE system performance, operation and effectiveness can be monitored by measuring flow rates, pressure distribution and/or vapor concentrations at extraction points, monitoring probes, and at treatment system influent and effluent locations.

The most significant obstacle to implementation of SVE at the Hi-Mill site is the shallow depth to ground water. The water table would have to be depressed in suspected source areas using conventional pumping or vacuum dewatering techniques in order to operate the SVE system.

Cost: The costs associated with routine application of SVE technology are relatively low, when compared to other source control technologies. However, the cost associated with construction and operation of an SVE system at the Hi-Mill site would be relatively high. This is due to the additional costs for dewatering that would be required in combination with the SVE system.

In conclusion, because of the limiting site conditions (i.e., high water table) discussed in this Section, SVE will not be retained as an applicable technology for remedial action at the Hi-Mill site.

3.3.4 Vacuum Enhanced Recovery

The limiting effect that the available drawdown in the shallow ground-water flow system at the Hi-Mill site has on conventional ground-water pumping technologies was discussed previously in Section 3.2. However, vacuum enhanced recovery is a technology that can be used in formations with low permeabilities and/or limited saturated thicknesses to increase the yield and associated capture zone of a ground-water pumping well (Blake, et. al. 1990). Where the saturated thickness of a formation is extremely limited, application of a vacuum may result in complete dewatering of the formation in the vicinity of the well. Continued application of the vacuum after dewatering has occurred will result in the venting of clean air through the dewatered sediments. Therefore, depending on the specific hydrogeologic conditions, this technology can be used for ground-water recovery/gradient control or dewatering and vapor recovery.

Ground-water flow to a pumping well (for unconfined conditions) is a function of the transmissivity of the aquifer and the gradient that is created towards the extraction point. In general, the lower the transmissivity and the steeper the slope of the gradient, the smaller the "capture zone" will be for a pumping well. The capture zone is the parabolic shaped zone of contribution that is associated with any pumping well. All water contained within the capture zone ultimately reaches the pumped well. Knowledge of a given recovery well's capture zone is essential to determining the well's effectiveness in meeting the objectives of an active remediation system. The capture zone of a recovery well can be increased by increasing the pumping rate from the well; however, the maximum pumping rate that can be sustained in a recovery well is limited by the available drawdown in the well. The drawdown is equal to the difference between the static water level (H, ft) and the dynamic or pumping water level (h_d, ft). The pumping rate from the well can only be increased to the rate at which the associated drawdown does not exceed the total saturated thickness of the formation.

Vacuum enhanced recovery is based on the principle that the hydraulic gradient to the well, and consequently the yield can be increased without lowering the pumping level in the well by applying a vacuum (negative pressure) to the well head (Blake 1986). The applied vacuum reduces the pressure head that exists at the pumping water level which in turn acts to increase the hydraulic gradient to the well. The resulting "effective" drawdown is equal to the difference between the static water level (H) and the pumping water level (h_d) plus the amount of vacuum applied. Neglecting the effects of well losses, the effective drawdown in the well would be increased by an amount equal to the applied vacuum.

Much larger vacuums (i.e., 10 to 20 inches Hg) are applied during vacuum enhanced recovery than are used with soil vapor extraction systems. The hydrogeological factors that influence the effect of vacuum enhanced recovery are the hydraulic conductivity, the saturated thickness of the aquifer and heterogeneities in the formation. The distribution of the vacuum effects will be dependent on the primary and secondary permeabilities that may be present in formations consisting of interbedded layers of fine and granular materials.

Effectiveness: The hydrogeologic conditions that exist at the Hi-Mill site are suitable for consideration of the use of vacuum enhanced recovery. The geometric mean of the hydraulic conductivity measured in the shallow flow system (brown clay unit) at the site was 1.81×10^{-4} cm/sec. This value is based on measurements of hydraulic conductivity from baildown tests conducted by Techna during the Phase I remedial investigation. Hydraulic conductivities on the order of 1×10^{-4} cm/sec are within the range that is recommended in case studies on the use of vacuum enhanced recovery (Blake et al. 1990; Blake 1986).

The design of a vacuum enhanced recovery system must be supported by pilot tests that measure the response of the formation (i.e., well yield, drawdown, radius of influence, etc.) to the applied vacuum. The effectiveness of the technology can be determined from the results of the pilot tests. The final design configuration for a vacuum enhanced recovery system would also be dictated by the results of the pilot tests. Options for system configuration include: (1) ground-water recovery and gradient control; (2) combined ground water/vapor recovery; and (3) dewatering and vapor recovery.

Implementability: The construction methods for vacuum enhanced recovery are similar to those that would be employed for soil vapor extraction. These methods include rotary drilling, well installation, installation of underground piping, installation of mechanical equipment, and electrical power supply and connections. As was presented in the discussion on soil vapor extraction, these construction methods are conventional in nature and well documented.

Since vacuum enhanced recovery results in the collection of the total fluids (i.e., groundwater, vapor and liquid phase) within the zone of influence of the system, treatment of the recovered fluids requires equipment for phase separation. The separation equipment, which would include air/water separators and oil/water separators is readily available from equipment manufacturers. The vacuum equipment required for an enhanced recovery system is more specialized than regenerative and centrifugal blower equipment typically used for soil vapor extraction. Because of the extremely large vacuums that are required (i.e., 10-20 inches Hg), particularly in formations with low permeabilities, more complex liquid ring pump systems are used.

Although compliance with the administrative requirements associated with vacuum enhanced recovery would be feasible, these requirements would be more extensive than those for an SVE system. In addition to air permit requirements for the recovered vapors, a wastewater discharge permit would also be required for the treated ground water.

Cost: The costs associated with implementation of a vacuum enhanced recovery system at the Hi-Mill site would be relatively high. Contributing to the high relative cost for this technology are the power requirements for the vacuum system. The large vacuum requirements for this technology results in high operating costs. In addition, equipment must be provided for treatment of both a liquid and gas phase.

Vacuum enhanced recovery will be retained as an applicable technology for remedial action at the Hi-Mill site.

3.3.5 Air Sparging/In-Situ Air Stripping

Air sparging and in-situ air stripping are in-situ mass transfer techniques which have been used to remove VOCs dissolved in ground water. Removal of these compounds is achieved by injecting compressed air into the saturated zone through an air sparging nozzle designed to distribute the air uniformly. As the air rises through the saturated zone, the air bubbles contact dissolved and adsorbed phase contaminants causing the VOCs to volatilize. When this VOC-laden air reaches the overlying unsaturated zone, it is collected by a vapor extraction system.

Air sparging and in-situ air stripping basically differ only in the configuration that is used to deliver the compressed air. The air sparging approach utilizes air injection wells to deliver the compressed air to the saturated zone. In an in-situ air stripping system, compressed air is forced through a horizontal sparging pipe installed in the bottom of a subsurface drain.

In each case, the vapor extraction component of the system would consist of a central blower station connected to extraction well(s) or trenches that are located near the air injection points. Depending on the concentration of VOCs present in the extracted air, treatment may be required prior to discharge of the air emissions to the atmosphere.

Effectiveness: The use of air sparging technology at the Hi-Mill site would require an integrated system consisting of air sparging wells and vapor extraction wells. A review of the chemical properties of the primary VOCs (i.e., TCE, 1,2-DCE and VC) detected at the site can be used to provide an initial assessment of the potential effectiveness of this technology. The conceptual model of mass transfer that occurs in the saturated zone with air sparging is comparable to a packed tower aeration system. As is the case with an air stripper, the injected air flows through the water column across a packing material, which in this case consists of the saturated zone soils.

The relative strippability of a compound can be determined by its Henry's Law constant. The Henry's Law constant is a measure of the chemical partitioning between air and water at equilibrium. References in the available literature indicate that dissolved VOCs with Henry's Law constants greater than 160 atm can be readily air stripped from solution (Nyer 1993).

Once the compounds have been volatilized by the pressurized air injected below the water table, they are removed from the vadose zone by a vacuum extraction system. A commonly used measure of the potential effectiveness of venting technologies for removal of a particular contaminant is the vapor pressure of the compound (Angell 1991). The vapor pressure of a compound is the pressure of its vapor in equilibrium with its pure liquid or solid phase. Generally, a compound is considered to be amenable to vacuum extraction if its vapor pressure is at least 1.0 mm Hg or greater.

The Henry's Law constants and vapor pressures of TCE, 1,2-DCE and VC are listed below.

Compound	*Henry's Law Constant*[(a)] @ 20°C (atm)	*Vapor Pressure*[(b)] @20°C (mm Hg)
TCE	544	60
1,2-DCE (*trans*)	429	200
VC	355,000	2600

(a.) Ref. Ground-Water and Soil Remediation, E. Nyer, 1993.
(b.) Ref. Handbook of Environmental Data on Organic Chemicals, K. Verschueren. 1983.

These primary VOCs have been detected in soil and ground-water samples collected from the brown clay unit at the site. The chemical characteristics of these compounds, as measured by their respective Henry's Law Constants and vapor pressures are certainly conducive to removal utilizing air sparging/vacuum extraction.

In addition to the relative volatility of the compounds to be removed, however, the expected distribution of the injected air must be considered when evaluating the potential effectiveness of air sparging. In this regard, the geologic and hydrogeologic conditions at the Hi-Mill site are not favorable for the use of air sparging. In order to be effective for mass transfer, the air injected below the water table must travel vertically through the saturated zone. This allows adequate contact between the injected air and the dissolved and adsorbed phases of the compound. Therefore, site conditions consisting of uniform geology are preferred for air sparging applications. Where interbedded sediments of varying permeability are present, the effectiveness of air sparging will be greatly reduced. Air sparging is generally not considered in situations where the horizontal conductivity (k_h) is less than 1×10^{-3} cm/sec. The value of the geometric mean for the horizontal hydraulic conductivity of the brown clay unit that was measured during the Phase I remedial investigation was 1.81×10^{-4} cm/sec.

Another problem associated with the use of air sparging in heterogeneous formations with low permeabilities is lateral spreading of the affected ground water. When the vertical air flow is restricted by a low permeability layer (e.g., clay), the pressurized air will flow preferentially through any seams or lenses of higher permeability materials (e.g., sands and/or silts) that are encountered. This can have the effect of spreading dissolved phase constituents radially from the air injection point.

Implementability: The factors that would affect the implementability of air sparging technologies are similar to those that were discussed for soil vapor extraction (Section 3.3.3).

These factors include the types of services and equipment required, potential construction interferences, and the need for modifying technologies (e.g. dewatering) due to the limiting site conditions.

Conventional construction equipment and services are used in the installation of air sparging systems. Some of the required services would include: rotary drilling, well installation or trenching, installation of underground piping, installation of mechanical equipment, and electrical power supply and connections. These types of services would be readily available locally. If treatment of the recovered vapors were necessary prior to discharge to the atmosphere, specialized equipment (e.g., vapor-phase granular activated carbon (GAC), catalytic oxidation, etc.) would be required. If a non-destructive method of emissions control were used, such as vapor-phase GAC, the treatment residuals would require further management at an off-site location.

Installation of air sparging and vapor extraction wells might be restricted by underground obstructions such as building foundations and buried utilities. This could result in a greater number of wells being used than might otherwise be required.

As was the case for soil vapor extraction, a major impediment to the implementation of air sparging at the Hi-Mill site is the shallow depth to ground water. The available vadose zone would be restricted further by the upswelling of the water table that occurs in the vicinity of an air sparging well.

Cost: The cost associated with implementation of air sparging technologies at the Hi-Mill site would be relatively high. Contributing to the relatively high cost for this technology would be the need for ground-water control measures to prevent the potential for lateral spreading of affected ground water from the air injection point, due to the heterogeneous nature of the brown clay unit.

In conclusion, because of the limiting site conditions (i.e., low hydraulic conductivity, heterogeneous formation, and high water table) discussed in this Section, air sparging will not be retained as an applicable technology for remedial action at the Hi-Mill site.

3.4 SUMMARY OF APPLICABLE REMEDIAL TECHNOLOGIES

The screening evaluation of the targeted list of potentially applicable remedial technologies for the Hi-Mill site was presented in the preceding sections. The remedial technologies that have been retained after the screening process include deed restrictions, ground-water monitoring and vacuum enhanced ground-water recovery.

The technologies that were eliminated as a result of the screening evaluation included soil vapor extraction and air sparging. Both of these technologies were eliminated from further consideration due to geologic and hydrogeologic constraints that would limit their effectiveness at the Hi-Mill site. These site limitation include heterogeneities in the brown clay unit beneath the site, extremely low transmissivities (< 50 gpd/ft) in the shallow flow system, shallow depth to ground water, and small saturated thickness in the brown clay unit.

Application of either soil vapor extraction or air sparging under these conditions would likely require the use of additional technologies (e.g. ground-water pumping) to modify the existing site conditions. Since an alternate technology (i.e., vacuum enhanced recovery) is available that may be directly applicable to the hydrogeologic setting, there is no advantage to evaluating technologies that would also require the use of modifying technologies. Although vacuum enhanced recovery has been used in similar settings, the hydrogeologic conditions at the

Hi-Mill site may represent the practical limits for use of the technology. Site-specific pilot testing would have to be conducted to determine the actual effectiveness of vacuum enhanced recovery for the geologic and hydrogeologic conditions at the Hi-Mill site.

The remedial technologies that were retained after screening have been assembled into the following remedial action alternatives:

- No Action
- Institutional Controls
  - Deed Restrictions
  - Ground-Water Monitoring
- Active Treatment
  - Vacuum Enhanced Recovery

A detailed description of each of these alternatives is provided in the next section of this report (Section 4.0). In Section 5.0 of the report, each of the remedial action alternatives is analyzed in accordance with the nine evaluation criteria presented in the National Contingency Plan (40 CFR 300, Subpart E, Section 300.430, effective April 9, 1990).

4.0 DESCRIPTION OF REMEDIAL ACTION ALTERNATIVES

This section presents detailed descriptions of the potential remedial action technologies which could be applied as remedies for VOC impacts to site soils and ground water related to past activities at the Hi-Mill site. The section has been subdivided for clarity, in accordance with each of the three principal remedial alternatives: the No Action alternative, institutional control alternative, and active treatment alternative.

4.1 NO ACTION ALTERNATIVE

This alternative assumes that no further remedial action of any kind will be implemented at the site to remediate either the VOC-impacted on-site and/or off-site soils or ground water. Evaluation of the No Action alternative is required under the guidelines set forth by the NCP.

The no action alternative would allow the VOC-impacted shallow ground water delineated during the Remedial Investigation (Figure 3) to potentially continue migrating downgradient along the M-59 median. Shallow ground water impacted by VOCs would, under this alternative, be subject to passive biodegradation (if it should occur) and/or natural attenuation. No ground-water monitoring would be utilized under this alternative to detect any future potential migration of impacted ground water.

The shallow site soils found to be impacted by VOCs would similarly be allowed to remain in place. Organic compounds contained within the site soils would undergo passive biodegradation, and would be gradually desorbed from the soil by infiltrating water. Leached organics would eventually migrate downward to the shallow site ground water (if not biodegraded) where lateral transport may occur. VOC-impacted water reaching the water table would then migrate downgradient and would be subjected to continued passive biodegradation.

4.2 INSTITUTIONAL CONTROLS ALTERNATIVE

Deed restrictions and long-term ground-water monitoring of the shallow flow system are potential options under consideration as part of the institutional controls alternative. Since an underlying assumption in the development of remedial action objectives is that the potential exposure to impacted soils and ground water should be minimized, these institutional controls are assumed to be required for each ground-water alternative except No Action. Presented in the following subsections are descriptions of the deed restrictions and ground-water monitoring options.

4.2.1 <u>Deed Restrictions</u>

Deed restrictions could be used as a means to prevent the Hi-Mill Manufacturing site from being sold for the purpose of residential development. These restrictions could be implemented to require that any future use of the property be limited to industrial use only. Such restrictions would limit potential exposure to impacted site soils and ground water by industrial workers only. Deed restrictions would also be designed to limit the installation of water supply wells in the shallow flow system, thus, preventing potential human and animal contact with impacted shallow ground water.

According to Section 10c of the Michigan Environmental Response Act (Public Act 307), any property transactions including sites that are known to be contaminated, must include certain disclosures related to the nature and extent of the contamination between the seller and buyer of the property. These provisions in Public Act 307 aid in minimizing the unintentional violation of deed restrictions developed for contaminated sites and should prove useful in bolstering the effectiveness of deed restrictions if applied at the Hi-Mill site.

4.2.2 Ground-Water Monitoring

Ground-water monitoring may be utilized to monitor the migration, passive biodegradation (if it should occur), and/or natural attenuation of impacted ground water in the shallow flow system. Limited monitoring of the intermediate flow system northwest of the site would also be employed to insure that impacted water will not migrate downward from the shallow flow regime. Presented in Figure 23 are the locations of monitoring wells which are proposed for monitoring at the site for the purpose of establishing an estimated cost for this task for this feasibility study report; the actual number and location of wells are subject to USEPA approval. The monitoring network will consist of 11 existing on-site shallow monitoring wells (SW-1, SW-3, SW-4, SW-5, SW-6, SW-10, SW-11, SW-12, SW-14, SW-15, and SW-21); five proposed new off-site shallow monitoring wells; one existing shallow off-site monitoring well (SW-2); one proposed new off-site intermediate monitoring well; one existing off-site intermediate monitoring well (IW-1); existing off-site shallow piezometers P-11B, P-12, and P-13B; and existing staff gauges SG-1, SG-2, SG-3, and SG-4. This proposed monitoring network will be used in the event that the institutional controls alternative is implemented, and does not represent the monitoring system which would be used in the event that an active ground-water treatment alternative is implemented. The monitoring network for the active treatment alternative is discussed in Section 4.3.1.5.

Data collected from the existing on-site shallow wells proposed for long-term monitoring of the ground-water will be used to insure that impacted shallow ground water is not discharging to any of the adjacent surface waterbodies in concentrations in excess of acceptable levels. The three new off-site shallow monitoring wells proposed for the M-59 median would be used to track the movement of the off-site concentrations of TCE detected, the leading edge of the plume, and the upgradient edge of the plume. The new and existing off-site shallow and intermediate wells proposed for completion and monitoring on the northwest side of M-59 will be used to monitor whether the plume is migrating toward the surface water features located northwest of Hi-Mill, and to determine whether impacted ground water from the shallow zone may be discharging to the intermediate flow system.

For the purpose of cost estimation for this feasibiltiy study report, it is assumed that ground-water samples will be collected from all of the proposed ground-water monitoring wells listed above, on a quarterly basis for a period of three years. Samples will be analyzed for the Target Compound List (TCL) VOCs only. Ground-water elevations will also be collected from all of the wells and piezometers in the proposed monitoring network on a quarterly basis for three years. Following three years of quarterly monitoring, ground-water monitoring of the network will be performed annually until such time as passive biodegradation (if it should occur) and/or natural attenuation of the shallow impacted ground water has reduced potential risks to human health and the environment to acceptable levels.

Quarterly monitoring reports will be prepared and submitted to USEPA and MDNR for a period of three years until the commencement of annual monitoring activities. An annual report will be prepared and submitted to USEPA and MDNR on an annual basis until such time as further monitoring is deemed unnecessary. Quarterly and annual monitoring reports will be used to assess whether further action (e.g., expanded monitoring or deed restriction placement, active treatment of soil or ground water, etc.) is required to address potential risks to human health and the environment as a result of the continued migration of impacted ground water. It may be necessary to augment the proposed monitoring network by either adding additional monitoring points further downgradient, or by deleting unnecessary upgradient monitoring points as the migration and passive biodegradation of impacted ground water progresses over time. Quarterly and annual monitoring reports will be utilized to address whether changes in the monitoring network will be necessary.

4.3 ACTIVE TREATMENT ALTERNATIVE

Based on the evaluation and screening of the targeted list of potential remedial technologies (see Section 3.3), vacuum enhanced ground-water recovery has been selected as the active treatment alternative (Alternative 3) for detailed evaluation in this Feasibility Study. Two different scenarios for the active treatment alternative will be considered. The first scenario consists of a vacuum enhanced recovery system designed to address on-site soils and ground water that have been impacted by volatile organic compounds (VOCs), primarily TCE, 1,2-DCE and VC (Alternative 3A). The second scenario (Alternative 3B) consists of a vacuum enhanced recovery system designed to address affected ground water in the M-59 median, in addition to the on-site soils and ground water. Alternative 3B has been evaluated at the request of USEPA.

The extent of the impacted areas, both onsite and offsite is defined by the risk-based cleanup levels that have been established for ground-water and soil at the Hi-Mill site (see Section 2.4.2). The calculated risk-based cleanup levels are based on the results of the baseline risk assessment (SEC Donohue 1992). The ground-water and soil risk-based clean-up levels were presented in Tables 3 and 4, respectively.

The results of soil and ground-water sampling conducted during the Phase I and II remedial investigation indicate that the most extensive impacts to soil and ground water at the site are associated with TCE. A summary discussion on the nature and extent of contamination at the Hi-Mill site is presented in Section 2.2.1 of this report. A more extensive presentation of this information is provided in the report entitled, *"Final Remedial Investigation Report, Hi-Mill Manufacturing Company"* (Geraghty & Miller, Inc. 1993). The distribution of TCE that exceeds the risk-based cleanup levels in on-site soil and ground water (see Figure 3), and also ground water within the M-59 median (see Figure 19) has been used to identify the control areas for the active treatment alternative scenarios.

4.3.1 Vacuum Enhanced Recovery Onsite (Alternative 3A)

A ground-water flow model and a vapor flow model were developed to simulate the effect of Alternative 3A on the shallow flow system at the Hi-Mill site. A detailed discussion that describes the basis of model code selection and development of the conceptual model for the site is presented in Appendix A.

4.3.1.1 Ground-Water Recovery

Alternative 3A consists of hydraulic recovery/containment of on-site ground water that exceeds the risk-based cleanup levels that have been established for ground water at the Hi-Mill site. The ground-water flow model was used to estimate the ground-water recovery rates and well placement required to meet this objective. Figure 24 illustrates the optimum model simulation that was generated for ground-water capture under Alternative 3A. Eight vacuum enhanced recovery wells are required to provide recovery/gradient control of affected on-site ground water. The wells have been placed around the Hi-Mill manufacturing building in a pattern designed to capture ground water from suspected source areas, and also prevent migration of on-site ground water that exceeds the cleanup levels.

Four general zones of contamination (Zones A, B, C and D) have been highlighted on Figure 24. These zones correspond to the following site areas:

- Zone A; former above-ground solvent storage tank area.
- Zone B; existing above-ground solvent storage tank area.
- Zone C and D; areas of ground water potentially affected by accidental release of TCE during construction of building addition.

The simulated water levels and fluid particle paths under pumping conditions are shown on Figure 24. In this simulation, each of the eight recovery wells are pumping at an average of 0.03 gpm. The low well yields are a result of the extremely limited transmissivity of the brown clay unit. However, at these pumping rates the capture zone analysis indicates that ground water emanating from the identified contamination zones is contained by the eight recovery wells. The capture zone of each of the recovery wells is illustrated on Figure 24 using "particle" tracking. The ground-water flow model simulates the release of fluid particles from the limits of the contamination zones, and then tracks their motion under the simulated pumping conditions to determine if the particles are captured by the recovery wells. The fluid particle tracks are shown on Figure 24 as the solid lines that originate from the outer edges of the contamination zones and terminate at the recovery wells. All of the released fluid particles under the simulation for Alternative 3A are captured by the eight recovery wells.

It is important to note that the simulated pumping rate of 0.03 gpm in each of the recovery wells assumes best-case conditions. Each of the pumping wells uses the maximum available drawdown in the brown clay unit. In addition, the recovery wells are assumed to be 100 percent efficient. It is unlikely that these pumping rates could actually be sustained, due to the limited available drawdown and the well inefficiencies that result from normal drilling damage during well construction. However, Blake, et.al (1990) have found that vacuum enhanced recovery wells in similar low permeability formations can support pumping rates that are 3 to 5 times higher than conventional recovery wells. Unfortunately, the flow model cannot be used to predict the increased well yields that would result with vacuum enhanced recovery. The actual pumping rates that could be achieved at the site, for both conventional and vacuum enhanced recovery can only be determined from site-specific pilot test information.

4.3.1.2 Vapor Recovery

By design a vacuum enhanced well will recover the total fluids within the zone of contribution of the well. The total fluids will consist of ground water, soil vapor and any free-phase liquids that may be present. The vapor flow model of the vadose zone developed for the site (Appendix A) was used to determine the necessary air flow rates and applied vacuum required to influence the identified zones of contamination (Zones A, B, C and D) where residual soil contamination may exist.

The areal influence, vacuum distribution and vapor flow rates of the simulated vapor recovery component of Alternative 3A are shown on Figure 25. The vacuum distribution (i.e., inches of water) emanating from each of the eight vacuum enhanced recovery wells is represented by contour intervals of 10 inches of water vacuum. A vacuum of 0.05 inches of water has been assumed as the effective influence of the vapor recovery component of the vacuum enhanced recovery wells. The suspected former source areas in Zone A and B are located in areas with greater than 10 inches of water vacuum. The simulated vapor extraction rate from each of the individual wells is listed on the next page:

Well Location	Flow Rate (cfm)
RW-1	33
RW-2	2.5
RW-3	2.5
RW-4	2.5
RW-5	2.5
RW-6	2.5
RW-7	2.5
RW-8	57

The combined vapor flow rate from the eight simulated vacuum enhanced recovery wells is approximately 100 cfm.

4.3.1.3 Treatment System

For the purpose of evaluating alternatives in this Feasibility Study report, a representative treatment process has been selected for Alternative 3A to separate and treat the total fluids recovered by the vacuum enhanced system. If Alternative 3A were to be implemented at the Hi-Mill site, the actual treatment system components and configuration might vary based on constituent and concentration data obtained during pilot testing of the system.

A process flow diagram of the representative treatment system is presented in Figure 26. The combined total fluids flow from the vacuum enhanced recovery wells would be pumped to an air/water separator for phase separation. The recovered liquids (i.e., ground-water and free-phase liquids) would then be pumped by a transfer pump to an oil/water separator. The oil/water separator would consist of a coalescing-type plate separator unit for removal of any emulsified free-phase liquids or suspended solids. Any free-phase liquids which accumulated in the oil/water separator would be drained into a 55-gallon collection drum. Disposal of accumulated free-phase liquids would be performed by simply changing-out the full 55-gallon drum with an empty drum and contracting a licensed disposal company to handle and transport the collected free product. If recovered free-phase liquids were in a recyclable state, Hi-Mill's existing recycling contractor could be utilized to handle the recovered organic liquids.

The separated ground water would flow to a diffused aeration unit where primary treatment for removal of VOCs would occur. The discharge from the diffused aeration unit would then be pumped to a liquid-phase granular activated carbon (GAC) bed for final polishing prior to discharge. The need to polish the effluent from the diffused aeration unit would be dependent on the actual concentration of VOCs in the influent from the recovery wells, and the effluent limits for the selected discharge point. The aeration unit would be vented to enable collection of the diffused air stream containing the desorbed VOCs.

The vented air emissions from the aeration unit would be combined with the vapor phase from the initial air/water separator and treated prior to discharge to the atmosphere, if necessary. The representative treatment process selected for Alternative 3A assumes that vapor-phase GAC will be used to treat the vapors from the recovery wells and the emissions from the aeration unit. The final selection of the air treatment process would be subject to change pending the results of the pilot tests. Vinyl chloride is one of the primary VOCs that has been detected in ground water at the Hi-Mill site. Due to its extremely high carbon-usage rates and rapid breakthrough time, vapor-phase GAC treatment is not recommend for VC. Depending on the recovered vapor concentrations measured during pilot testing, alternate air treatment technologies (i.e, catalytic oxidation or thermal treatment), or operational adjustments might be necessary to address VC emissions.

Under Alternative 3A, the total fluids from the eight vacuum enhanced recovery wells would be conveyed via a common header pipe to a centrally located vacuum pump station. The vacuum pump and treatment equipment, including the oil/water separator, diffused aeration unit, liquid and vapor-phase GAC units would be housed in a skid-mounted enclosure placed on a concrete slab. The treatment enclosure would secured by a chain-link fence.

4.3.1.4 Disposal Options

The treated water effluent, and possibly the air emissions from the treatment system under Alternative 3A, would normally require discharge permits. However, CERCLA 121(e)(1) provides that no federal, state, or local permit shall be required for remedial actions at Superfund sites. Nonetheless, the substantive requirements contained within the permitting requirements will be complied with. For comparison purposes, a discussion of the disposal options and the associated permit requirements (including the administrative requirements that are not applicable to CERCLA actions) is presented in the following sections.

Water Discharge. The options available for discharging treated ground water include surface water discharge and ground-water discharge; sanitary sewer discharge is not an option on this site because it is located in an area that has no sanitary sewers available for use. Discharge to surface water or ground water normally requires a National Pollutant Discharge Elimination System (NPDES) permit or a Ground Water Discharge permit, respectively. However, CERCLA 121 (e)(1) provides that no Federal State or local permit shall be required for remedial actions conducted on-site (on-site is defined by Section 300.400 (e)(1) of the NCP as the areal extent of contamination and all suitable areas in very close proximity). Therefore, no permits are required for this action, although the permitting authorities may be consulted to guide the selection of appropriate discharge locations and parameters. The following paragraphs describe the NPDES and Ground Water Discharge permitting processes as a reference to what normally is required to obtain approval for these discharges on sites where these permits are required.

The NPDES was initiated by the Federal Congress through the enactment of "The Federal Water Pollution Control Act Amendments of 1972". The NPDES permitting process in Michigan is governed by Part 21 of the Rules of the Michigan Water Resource Commission pursuant to Act 245, Public Acts of 1929, as amended. Requirements for obtaining a NPDES permit include the completion and submittal of an Industrial and Commercial Wastewater Discharge Application including a hydrogeologic study, review by staff of the Surface Water Quality Division of the MDNR, public notice of proposed permit and an ensuing thirty day public comment period, and a determination of issuance or denial of the permit by the Water Resource Commission.

Ground Water Discharge Permits are required under the Michigan Water Resources Commission Act (Act 245, P.A. 1929, as amended). Staff members of the MDNR review and make recommendations about permit applications. The Ground Water Discharge Permit Process involves a pre-application meeting with the Waste Management Division of the MDNR, completion and submittal of an Industrial and Commercial Wastewater Discharge Application including a hydrogeologic study, review by staff of the Waste Management Division of the MDNR, public notice of proposed permit and an ensuing thirty day public comment period, and a determination of issuance or denial of the permit by the Water Resource Commission.

Determination of maximum effluent concentrations are either water quality based limits or technology based limits, which ever is lower. For the case of our proposed remedial system, technology based limits will govern. In general, NPDES technology based discharge limits for the VOCs encountered at the Hi-Mill site are 5 micrograms per liter (μg/L), except for vinyl chloride which is 3 μg/L. Ground Water Discharge technology based discharge limits for VOCs are 1 μg/L.

The available options for surface-water discharge location in order of preference are listed below:

- Discharge to the North Arm of Waterbury Lake.
- Discharge to Waterbury Lake.
- Discharge to Target Pond.
- Discharge to a drainage ditch along M-59.
- Discharge to a catch basin along M-59.

Due to the anticipated administrative implementation difficulties associated with the drainage ditch and catch basin options, discharge to the North Arm of Waterbury Lake, the main body of Waterbury Lake, or Target Pond is recommended. However, it is recommended that a meeting between the Surface Water Quality Division of the MDNR be coordinated to ensure an agreeable location is selected.

The North Arm of Waterbury Lake has a surface area of approximately 2 acres. It is not surficially connected to the main portion of Waterbury Lake, however, surface water elevations indicate the two bodies are hydraulically interconnected through the levee located between them. If the two lakes are indeed interconnected, as surface water elevations indicate, it may be more appropriate to discharge to the higher-volume North Arm of Waterbury Lake than to Target Pond.

The main body of Waterbury Lake has a surface area of approximately 35 to 40 acres, which makes the main body a more attractive discharge point due to the larger volume of the lake. Unfortunately, the main body of the lake is located further away from the facility than either the North Arm or Target Pond.

Target Pond has a surface area of approximately 8 to 10 acres, but does not have a surface-water drainage outlet. Discussions with the Surface Water Quality Division indicate this is a potential discharge location but problems may arise due to its limited volume and surface area and the absence of an outlet for drainage flow. However, this may be an appropriate discharge point depending on the volumetric flow rate of the treated effluent to be discharged.

Discharge to the drainage ditches along M-59 has been meet with initial disapproval from the MDNR due to surface contamination that may be present in those areas. Permission must be obtained from the Michigan Department of Transportation to discharge to a catch basin located along M-59. According to the MDNR this is very difficult and no past instances could be quoted in which permission has been granted. Both of these options (with the exception of discharge to contaminated portions of the M-59 drainage ditch) will be considered should a discharge to the North Arm of Waterbury Lake or Target Pond become unfeasible.

Air Discharge. Air Use Permits and Permits to Install are routinely required by administrative rules pursuant to the Air Pollution Act 348 of 1965, as amended, but are exempted under Section 121 (e)(1) of CERCLA. However, the active treatment alternative may require treatment of extracted soil vapors and air emissions from the ground water treatment system to meet the substantive requirements of the Air Pollution Act.

The remediation process may also have to meet the substantive requirements of the Michigan Air Pollution Control Commission Rule 702, which requires the use of best available control technology for emissions of VOCs. If the control technology implemented is shown to be of the best available technology, no additional analyses will normally be required.

4.3.1.5 Ground-Water Monitoring

The ground-water monitoring system for Alternative 3A would consist of the eight new proposed ground-water recovery wells (RW-1 through RW-8); four new off-site shallow monitoring wells; one new off-site intermediate zone monitoring well; existing off-site intermediate zone monitoring well IW-1; existing on-site shallow monitoring wells SW-1, SW-5, and SW-6; and existing off-site shallow monitoring well SW-2. These 18 wells would be monitored on a quarterly basis for three years for the Target Compound List (TCL) volatile organics. Ground-water elevations would also be collected from these wells on a quarterly basis for three years; and from wells SW-4, SW-9A, SW-10, SW-11, SW-12, SW-14, SW-15; piezometers P-11B, P-12, and P-13B; and staff gauges SG-1, SG-2, SG-3, and SG-4. (Figure 23).

Following the completion of three years of quarterly ground-water monitoring, it is assumed for feasibility study cost estimating purposes that monitoring activities would continue on an annual basis until such time as the recovery of impacted ground water had been deemed satisfactory. The collection of ground-water quality samples would provide data on the effectiveness and progress of remedial efforts. Ground-water levels collected from the monitoring network would be used to verify the capture of impacted ground water.

The monitoring of the eight proposed recovery wells would provide data on the concentrations of volatile organics being intercepted by the remedial system and on the loading to the on-site treatment system. Water quality data collected from wells SW-1, SW-5, and SW-6 would aid in monitoring the impact of recovery efforts on affected ground water near the margins of the plume. The installation and monitoring of proposed new shallow monitoring wells in the M-59 median and northwest of Hi-Mill across M-59 would allow for monitoring of the off-site portions of the plume, and would aid in assessing the affect of on-site recovery on off-site areas underlain by impacted shallow ground water. The monitoring of existing off-site wells SW-2 and IW-1 and the proposed new off-site intermediate zone well located directly across M-59 from the Hi-Mill plant would be used to insure that impacted ground water was not migrating away from the M-59 roadway area, and that affected water was not migrating downward into the intermediate flow regime.

4.3.2 Vacuum Enhanced Recovery Onsite/Offsite (Alternative 3B)

Under Alternative 3B, an off-site ground-water recovery component is added to the on-site ground-water recovery/containment elements of Alternative 3B. The extent of off-site impacts was defined by the risk-based cleanup levels for ground water that have been established for the Hi-Mill site (see Section 2.4.2.1). The risk-based cleanup levels for TCE, 1,2-DCE and VC (Table 3) were compared to the results of ground-water sampling conducted during the M-59 median investigation. The most extensive impacts to off-site ground water are associated with TCE (see Figure 19). The ground-water data from the median investigation were reviewed to delineate the extent of the area within the median where TCE concentrations exceed the risk-based cleanup level (200 μg/L). This area can generally be defined as the area within the M-59 median between piezometer locations P-11 and P-12.

4.3.2.1 Ground-Water Recovery

The ground-water flow model that was developed for the shallow flow system at the site was used to evaluate options for recovery of affected off-site ground water. Figure 27 illustrates the optimum model simulation that was generated for capture of affected ground water in the M-59 median under Alternative 3B. The shaded area on Figure 27 represents the zone of off-site ground water where TCE concentrations exceed the risk-based cleanup level of 200 μg/L. Model simulations indicate that a single conventional ground-water recovery well (RW-9) pumping at a rate of 0.13 gpm would provide recovery/gradient control of the affected off-site ground water. The on-site recovery/gradient control component of Alternative 3B would be identical to that described for Alternative 3A. Eight vacuum enhanced recovery wells, placed at the approximate locations shown on Figure 27 and pumping at a combined flow rate of 0.3 gpm comprise the on-site ground-water recovery component of Alternative 3B. The simulated pumping rates are based on the response of the shallow flow system to conventional recovery wells. The simulation also assumes that the pumping wells are 100 percent efficient. The actual increased yield from each of the recovery wells that would occur as a result of enhancing recovery with an applied vacuum, would have to be determined from site-specific pilot tests.

The simulated water levels and fluid particle paths under pumping conditions for the off-site recovery well (RW-9) under Alternative 3B are shown on Figure 27. The fluid particle tracks are shown on Figure 27 as the dashed lines that originate from the outer edges of the zone of affected ground water (shaded area) in the M-59 median. All of the released fluid particles under the simulation for Alternative 3B are captured by the recovery well. The simulated pumping rate for the off-site recovery well (RW-9) is higher than those for the on-site wells. This is due to the relatively higher transmissivity of the silt and sand sediments that become prevalent in the upper zone beneath the M-59 median. Therefore, because of the expected higher well yields the off-site recovery well would be operated as a conventional pumping well (i.e., no applied vacuum).

4.3.2.2 Vapor Recovery

The vapor recovery component of Alternative 3B would be identical to that described for Alternative 3A in Section 4.3.1.2. The areal influence, vacuum distribution and vapor flow rates for the simulated vapor recovery under this alternative are shown on Figure 25.

4.3.2.3 Treatment System

The treatment system for Alternative 3B would be identical to the representative treatment system (see Figure 26 for process flow diagram) described for Alternative 3A in Section 4.3.1.3, with the exception of changes to the ground-water conveyance system.

In order to convey ground water from the off-site recovery well to the treatment system located on the Hi-Mill property, a force main from the well would have to cross the northbound lanes of M-59. The force main would be installed inside a horizontal boring that would be drilled beneath the highway (i.e., jacked pipe undercrossing). Two separate horizontal borings would be required for the recovery well force main, and the electrical conduit to the well pump. The horizontal borings would be advanced from access pits dug on either side of M-59. The excavation pits would require sheet piling for reinforcement, and dewatering due to the shallow water table conditions. All construction activities associated with the off-site component of Alternative 3B would have to be coordinated with, and approved by the Michigan Department of Transportation (MDOT). In addition, an agreement would have to be negotiated with MDOT for access to its right-of-way for maintenance of the recovery well and equipment installed in the M-59 median.

4.3.2.4 Disposal Options

The disposal options for the treated ground water and air emissions from the treatment system under Alternative 3B, would be identical to those for Alternative 3A. A description of the disposal options is presented in Section 4.3.1.4.

4.3.2.5 Ground-Water Monitoring

The ground-water monitoring system proposed for Alternative 3B would consist of the same wells, piezometers, and staff gauges as suggested for Alternative 3A, except that the proposed off-site (Recovery Well) RW-9 would also be monitored. Monitoring activities for Alternative 3B would be performed in accordance with the methodologies and schedule proposed for Alternative 3A. The rational for the design of the Alternative 3B system is the same as presented for Alternative 3A (Section 4.3.1.5).

5.0 EVALUATION OF REMEDIAL ALTERNATIVES

5.1 SCREENING OF REMEDIAL ALTERNATIVES

The USEPA RI/FS Guidance Document (U.S. Environmental Protection Agency 1988) recommends that the developed remedial alternatives be screened against the general criteria of effectiveness, implementability and cost prior to conducting a detailed analysis of the alternatives. Through this initial screening, the number of remedial alternatives that are to be taken through detailed analysis can be reduced by screening out all except the most promising remedial alternatives.

However, due to the unique site conditions at the Hi-Mill site, a presumptive remedy approach was used to allow for the streamlined development of the most promising potentially viable remedial alternatives. Since only a limited number of potentially viable remedial alternatives could be developed, the remedial alternative screening process was not necessary and therefore was not conducted. By omitting the optional remedial alternative screening process, the developed remedial alternatives have all been carried through into the detailed analysis step. A description of the detailed analysis procedure along with a description and analysis of the individual remedial alternatives are presented in the following sections.

5.2 DESCRIPTION OF DETAILED ANALYSIS CRITERIA

In order to conduct a comprehensive, comparative analysis of the remedial alternatives, each of the remedial alternatives are assessed against the evaluation criteria that have been developed to address the statutory considerations listed under CERCLA, Section 121. The nine evaluation criteria utilized in assessing the Hi-Mill remedial alternatives are in accordance with the detailed analysis criteria specified within the current version of the NCP (40 CFR 300, Subpart E, Section 300.430, effective April 9, 1990). The nine evaluation criteria are listed as follows:

(1) Overall protection of human health and the environment.
(2) Compliance with applicable or relevant and appropriate requirements (ARARs)
(3) Long-term effectiveness and permanence.
(4) Reduction of toxicity, mobility, or volume through treatment.
(5) Short-term effectiveness.
(6) Implementability.
(7) Cost.
(8) State acceptance.
(9) Community acceptance.

During the detailed analysis, each alternative is assessed against each of the nine criteria. After analyzing the individual alternatives, a comparative analysis is performed to assess the relative performance of each alternative with respect to the evaluation criteria. It is during the comparative analysis, which is presented in Section 6.0, that the relative advantages and disadvantages of the alternatives are identified.

The evaluation criteria to be used in analyzing the remedial alternatives are defined in the following sections.

5.2.1 Overall Protection of Human Health and the Environment

This criterion is used to assess to what degree an alternative would eliminate, reduce or control the risks to human health and the environment through treatment, engineering controls, or institutional controls. It is an overall assessment of protectiveness that encompasses the assessment of other criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

5.2.2 Compliance with ARARs

This criterion is used to determine whether a remedial alternative meets all of its federal and state ARARs that have been identified by the regulatory agencies. A list of potential ARARs and a detailed analysis of ARARs for the Hi-Mill site are presented in Appendix B. If a particular ARAR can not be met by an alternative, then a determination should be made on whether a waiver of the ARAR, as allowed under Section 121 of CERCLA, would be appropriate. If a particular ARAR can not be met by an alternative, then a determination should be made on whether a waiver of the ARAR, as allowed under Section 121 of CERCLA, would be appropriate. Three types of ARARs (chemical-specific ARARs, location-specific ARARs, and action-specific ARARs) are considered in making this assessment.

5.2.3 Long-Term Effectiveness and Permanence

This criterion is used to assess whether a remedial alternative would carry a potential continual risk to human health and the environment after the remedial action would be completed. An evaluation is made as to the magnitude of the residual risk present after the completion of the remedial actions as well as the adequacy and reliability of controls that could be implemented to monitor and manage the residual risk that may be present.

5.2.4 Reduction of Toxicity, Mobility or Volume through Treatment

This criterion is used to assess to what degree a remedial alternative, by utilizing treatment technologies, would permanently and significantly reduce the toxicity, mobility or volume of the hazardous substances at the site. The assessment focuses on the magnitude, significance, and irreversibility of the reductions.

5.2.5 Short-Term Effectiveness

Short-term effectiveness refers to the degree to which human health and the environment would be affected during the construction and implementation of the remedial alternative. The protection of workers, the community, and the surrounding environment as well as the time to achieve the remedial response objectives are considered in making this assessment.

5.2.6 Implementability

The assessment of implementability considers both the technical and administrative feasibility of implementing a remedial alternative and the availability of services and materials required during implementation. The ability to construct and operate the technologies included as part of an alternative, the reliability of the technologies used, the ease of obtaining any necessary permits, the ease of undertaking additional remedial action if required, and monitoring requirements are considered in assessing the technical and administrative feasibility of implementing an alternative. The availability of treatment, storage capacity, disposal services, necessary equipment, and personnel are considered in assessing the availability of services and materials required for implementing a remedial alternative.

5.2.7 Costs

This criterion includes direct capital costs, operation and maintenance costs, and total present worth analysis associated with implementing a remedial alternative. The capital costs are divided into direct costs and indirect costs. Direct capital costs include construction costs, equipment costs, site development costs and disposal costs. Indirect capital costs include engineering expenses, legal fees and license or permit costs, start-up costs and contingency allowances.

Operation and maintenance (O&M) costs are post-construction expenditures necessary for the continued effective operation of a remedial action over a specified period. These costs include operating labor costs, maintenance materials and labor costs, auxiliary materials expenses, and energy costs. These costs also include disposal of residues, administrative costs, insurance and licensing costs, maintenance contingency funds, rehabilitation costs, and costs of periodic site reviews if required.

The cost estimates presented in this FS report were developed utilizing the Remedial Action Costing Procedures Manual (U.S. Environmental Protection Agency 1985); Means Building Construction Cost Data (Means 1992); Means Site Work Cost Data (Means 1992); quotations from various vendors and material suppliers; and engineering judgement based on experience at similar sites. In accordance with USEPA guidance, the cost estimates are expected to provide an accuracy of +50 to -30 percent (U.S. Environmental Protection Agency 1988).

After development of the capital and operation and maintenance costs, a present worth analysis of remedial action costs is conducted. A present worth analysis relates costs that occur over different time periods to present costs by discounting all future costs to the present value. This allows the cost of remedial alternatives to be compared on the basis of a single figure that represents the money required in today's dollars to construct, operate and maintain the remedial alternatives throughout their planned life. For the purposes of this detailed analysis, a 5% discount rate over a 30-year remedial performance period is assumed for the remedial alternatives (U.S. Environmental Protection Agency 1988).

5.2.8 State Acceptance

This criterion is used to discuss the comments and concerns the state may have regarding each of the remedial alternatives. This assessment can not be made until after the state provides its input to the USEPA's Proposed Plan. Since state acceptance of the remedial alternatives is unknown at this time, it is not addressed in the detailed analysis of alternatives.

5.2.9 Community Acceptance

This criterion refers to the comments and concerns the public may have regarding each of the remedial alternatives. This assessment can not be fully made until after completing the public comment period in which the public will have an opportunity to respond to the USEPA's Proposed Plan. Because the acceptability of the remedial alternatives to the community is not known at this time, it is not addressed in the detailed analysis of alternatives.

5.3 ALTERNATIVE 1 : NO ACTION

Alternative 1 is the No Action alternative. As its name implies, no further actions would be implemented at the Hi-Mill site to provide for source control or monitoring of the environmental media to determine if waste constituent releases were occurring. This alternative would simply be a continuation of the current situation at the Hi-Mill site. The assessment of the No Action alternative according to the nine criteria is presented below.

5.3.1 Overall Protection of Human Health and the Environment

The results of the baseline risk assessment (SEC Donohue 1992) conducted for the site concluded that the risks to human health and the environment posed by the current conditions at the Hi-Mill site are within acceptable health-based risk levels. Exposure to impacted surface soils do not result in significant human health risks, and there is currently no exposure occurring to the shallow ground water. As a result, the No Action alternative is expected to provide, at a minimum, a potentially adequate degree of protection to human health and the environment for the short term. However, ground-water monitoring would not be provided to detect potential further migration of the ground-water plume, and deed restrictions or ground-water use restrictions would not be implemented to prevent the exposure to impacted soils or ground water in the future. Therefore, the No Action alternative would be protective of human health and the environment under current conditions, but would not limit the potential for future increased risks to human health and the environment.

5.3.2 Compliance with ARARs

Since remedial actions would not be undertaken at the site, ARARs would not apply to the No Action alternative (Alternative 1) or the institutional controls alternative (Alternative 2). This is consistent with USEPA policy which has established that "No Action" alternatives, if selected as a remedy by the USEPA, do not need to comply with ARARs (U.S. Environmental Protection Agency 1989a). The active treatment alternatives (Alternatives 3A and 3B) must comply with ARARs (or be granted a waiver) as a minimum requirement for acceptability as a final remedial alternative for the site.

5.3.3 Long-Term Effectiveness and Permanence

The No Action alternative would not reduce or eliminate the potential risks involving direct contact with or ingestion of subsurface soils or ground water. Since ground-water monitoring would not be provided, the No Action alternative would be ineffective in determining whether continued protection of human health and the environment is being accomplished.

The current MDPH rules prohibiting the screening of drinking water wells within 25 ft bls would remain in effect (Rule 131, R325.1631, Paragraph 4), and would prevent the consumption of impacted ground water in the future. However, it is conceivable (although unlikely), that a non-potable water source could be tapped into the impacted portion of the aquifer in the future for irrigation purposes. The No Action alternative does not have any deed restriction provisions to prevent exposure to ground-water under this scenario. As a result, the No Action alternative would have a relatively low degree of long-term effectiveness for the protection of human health and the environment, and may fail to meet the remedial action objectives for the site. The issue of permanence is not applicable to the No Action alternative.

5.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action alternative would not employ active treatment and, therefore, would not reduce the toxicity, mobility or volume of the waste constituents at the site through treatment. However, the ongoing passive biodegradation (if it should occur) and/or natural attenuation of the constituents of concern would continue under the No Action alternative.

5.3.5 Short-Term Effectiveness

Since on-site construction activities would not be required, the No Action alternative would have a high degree of short-term effectiveness. This is due to the fact that the risks to human health and the environment, which were determined by the risk assessment to be presently acceptable, would not be increased during the implementation of this alternative.

5.3.6 Implementability

The evaluation of implementability is not applicable to the No Action alternative.

5.3.7 Costs

There are no capital, operation or maintenance costs associated with the implementation of the No Action alternative.

5.3.8 State Acceptance

The assessment of state acceptance can not be made until after the state provides its input to USEPA's Proposed Plan.

5.3.9 Community Acceptance

The assessment of community acceptance can not be made until after completing the public comment period in which the public will have an opportunity to respond to the USEPA's Proposed Plan.

5.4 ALTERNATIVE 2: INSTITUTIONAL CONTROLS

Alternative 2 represents the institutional controls alternative, and consists of the major components of deed restrictions and ground-water monitoring. The results of assessing Alternative 2 against the nine evaluation criteria are presented below.

5.4.1 Overall Protection of Human Health and the Environment

As stated previously, the current risks to human health and the environment associated with the existence of the Hi-Mill site are within acceptable health-based and environmental quality-based guidelines. Risks to human health and the environment associated with the continued, stable existence of the Hi-Mill site may therefore continue to fall within acceptable health-based and environmental quality-based guidelines. Implementation of institutional controls would further promote the continued protection of human health and the environment by limiting potential future exposure.

Deed restrictions would be effective in controlling any future land use in which human health and the environment might be jeopardized. Deed restrictions would also be effective in preventing any future use of potentially affected ground water by preventing the installation of water supply wells within a prescribed zone on or adjacent to the site. These restrictions would complement the existing MDPH restrictions prohibiting the installation of drinking water wells within 25 ft bls (Rule 131, R325.1631, Paragraph 4).

Ground-water monitoring would detect future plume movement and track additional waste releases to ground water, if they were to occur, so that potential impacts to human health and the environment could be assessed and future remediation efforts could be appropriately developed, if warranted.

Since Alternative 2 would not provide for enhanced source control, it is possible that significant expansion of the plume could occur some time in the future. However, the ground-water monitoring program would detect these changes in ground-water quality. Ground-water use restrictions would prevent the release from entering a viable exposure pathway. If necessary, future remedial actions could be implemented to abate potential risks to human health and the environment caused by a plume expansion. Since the current risks to human health and the environment are within acceptable limits, and since provisions would be implemented to monitor and to develop and implement additional remedial action (if necessary), Alternative 2 would provide protection to human health and the environment through monitoring, deed restrictions, and response as appropriate.

5.4.2 Compliance with ARARs

ARARs do not apply to Alternative 2.

5.4.3 Long-Term Effectiveness and Permanence

The long-term risks to human health and the environment associated with the Hi-Mill site involve the potential exposure to impacted ground water extracted from the shallow aquifer for the purpose of landscape irrigation. Although this scenario is unlikely, the implementation of deed restrictions at the site would further limit the potential for exposure to site waste constituents by the ground-water pathway. In addition, the ground-water quality monitoring system established with this alternative will detect significant releases of waste constituents (if any) into the ground water, and allow for the development of further remedial actions if necessary.

The major factors that would impact the long-term effectiveness and permanence of Alternative 2 are the adequacy and reliability of ground-water monitoring and the enforceability of the deed restrictions. If conducted by properly trained personnel, ground-water monitoring is a very effective and reliable means for detecting potential site releases. To ensure the accuracy of the ground-water monitoring program, adequate quality assurance/quality control measures would have to be taken during the sampling, transporting, and analyzing the ground-water samples. Deed restrictions with inherent ground-water use restrictions would be formulated with the knowledge and participation of the local authorities to assist in the successful implementation of the controls.

5.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The institutional controls provided under Alternative 2 would not employ active treatment and, therefore, would not reduce the toxicity, mobility or volume of the constituents found at the site through treatment. Alternative 2 does, however, include provisions to monitor the ground water to observe and record the passive biodegradation (if it should occur) and/or natural attenuation of the constituent concentrations within the plume.

5.4.5 Short-Term Effectiveness

No on-site construction activities would be provided as part of Alternative 2. Upon initiation of the ground-water monitoring program and deed restriction provisions, the remedial response objectives would be met. The lack of on-site construction activities and the short implementation period makes Alternative 2 very effective in the short term.

5.4.6 Implementability

A successful ground-water monitoring program could be easily implemented. Deed restrictions could also be easily implemented; however, it would require the assistance of local government officials and the cooperation of Hi-Mill owners.

5.4.7 Costs

The costs associated with the implementation of Alternative 2, rounded to the nearest $1,000, are $36,000 in capital costs and $88,000 in annual O&M costs for the first 3 years, and $23,000 in annual O&M costs for the next 27 years (see Table 6). The 30-year present net worth value of implementing Alternative 2 is therefore approximately $565,000.

5.4.8 State Acceptance

The assessment of state acceptance can not be made until after the state provides its input to the USEPA's Proposed Plan.

5.4.9 Community Acceptance

The assessment of community acceptance can not be made until after completing the public comment period in which the public will have an opportunity to respond to the USEPA's Proposed Plan.

5.5 ALTERNATIVE 3: ACTIVE TREATMENT

Alternative 3, the active treatment alternative, uses a vacuum enhanced recovery system as the primary method for vapor and ground-water recovery and treatment. The treatment system in Alternative 3 can be configured in two different ways to meet remedial action goals. Alternative 3A, the on-site configuration, consists of the following major components:

- Ground-water monitoring
- Deed Restrictions
- Vacuum enhanced recovery system
- Diffused aeration
- Vapor-phase granular activated carbon (optional)
- Surface water discharge

Alternative 3B, the on and off-site configuration, consists of the same basic components of Alternative 3A with the addition of a single ground-water extraction well located in the median of M-59 designed to assist in capturing the outer edge of the ground water plume.

The results of assessing Alternatives 3A and 3B against the nine evaluation criteria are presented below.

5.5.1 Overall Protection of Human Health and the Environment

As stated previously, the current risks to human health and the environment associated with the existence of the Hi-Mill site are negligible because no exposure to contaminants in the shallow aquifer is occurring and other contamination on-site is within acceptable health-based and environmental quality-based guidelines. Implementation of institutional controls as outlined for Alternative 2 will meet the remedial action goals by reducing the exposure potential that may occur using hypothetical future exposure scenarios. In addition to these controls, Alternative 3A utilizes the active treatment technologies associated with a vacuum enhanced recovery system to treat both the soils and ground-water impacted by the site, and Alternative 3B adds the use of an off-site ground-water extraction well designed to capture and treat the furthest reaches of the off-site ground-water plume. The treatment of the water and vapors extracted by the vacuum enhanced recovery system will be used to permanently remove the volatile organic constituents of concern to help meet the remedial action goals for the site.

Since Alternatives 3A and 3B provide for ground-water monitoring, deed restrictions, and enhanced source control, the alternatives will provide a substantial level of overall protectiveness. Since the current risks to human health and the environment are within acceptable limits, the efforts to actively reduce and control the site-related constituents of concern (in addition to the institutional controls) will further reduce the possibility of significant exposure to the constituents in the future.

5.5.2 Compliance with ARARs

Alternatives 3A and 3B will comply with all identified chemical-specific, action-specific and location-specific ARARs that apply to its remediation activities, including the substantive requirements of NPDES for ground-water discharge to adjacent surface water and the Michigan Air Pollution Control Act (see Table B-2, Appendix B).

5.5.3 Long-Term Effectiveness and Permanence

The long-term risks to human health and the environment associated with the Hi-Mill site involve the potential exposure to impacted ground water and subsurface soils. However, by limiting exposure to the impacted media and controlling the source of ground-water impact, the future significant exposure potential to the impacted media will be greatly reduced.

The major factors that would impact the long-term effectiveness and permanence of Alternatives 3A and 3B are associated with the adequacy and reliability of both the institutional controls (discussed in Section 5.4.3) and the various components of the vacuum enhanced recovery system. It should be noted that institutional controls are the *only* effective means to protect public health and the environment prior to the complete remediation of the ground-water and soils to risk-based levels. If and when the risk-based goals are met by treatment of the soils and ground water, the institutional controls can be lifted.

The vacuum enhanced recovery system utilized in Alternative 3A can be used to extract ground water and soil gas vapors under a variety of conditions, and the system would likely be much more effective than other remedial options when working in the thin, shallow, low permeability ground-water unit present at the Hi-Mill site. However, the complicated hydrogeology in the brown clay unit (shallow aquifer) creates a difficult setting to effectively treat the ground water and soils using any extraction or collection method. The low permeabilities and thin saturated thicknesses of the brown clay unit limit even the improved pumping rates that may be achieved using vacuum enhanced recovery techniques. Heterogeneities in the brown clay unit (interbedded sands, clays, and silts) will result in non-uniform preferential flow-paths for ground water within the unit. In addition, the discontinuous nature of ground-water within the shallow brown clay unit makes effective placement of extraction wells difficult. The modelling results for ground-water recovery (Appendix A) indicate that it may be possible to sufficiently control the source areas for ground-water impact through the placement of eight on-site ground-water recovery wells. However, the actual performance and operating parameters of the system (e.g., necessary pumping rates, actual extraction rates, radius of influence, etc.) cannot be determined without specific pilot test information.

In addition to the ground-water source controls and gas treatment controls offered by Alternative 3A, Alternative 3B provides for additional extraction and treatment of the impacted off-site ground water in the M-59 median. The successful extraction of this ground water, however, is under the same constraints and limitations as those discussed above for the on-site configuration.

The use of aeration as a means to separate VOCs from an aqueous mixture to the gas (air) phase is well proven for the primary VOC contaminants of concern at the Hi-Mill site (TCE, 1,2-DCE and vinyl chloride). If it is demonstrated to be necessary to treat the off-gas produced by the treatment system, the vapor-phase carbon system will effectively and permanently destroy the significant portion of the organic contaminants of concern within the air stream.

5.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The treatment technologies of diffused aeration and the optional vapor-phase GAC would effectively and permanently reduce the concentration of the VOCs found within the extracted vapors and ground water, thus reducing the toxicity and volume of these constituents at the site.

5.5.5 Short-Term Effectiveness

The construction activity associated with the implementation of Alternatives 3A and 3B that will present the most significant potential for exposure to site-related constituents of concern is the construction of extraction wells (and in the case of Alternative 3B the additional off-site extraction well and associated trenching and piping) at the site for use with the vacuum enhanced recovery system. The construction of the additional wells necessary for the implementation of Alternatives 3A and 3B should present no major short-term risks, but the trenching beneath M-59 as required by Alternative 3B will present additional short-term risks. The trenching associated with the jack and bore installation of a force main to transport extracted ground water to the on-site treatment facility would involve risks to structural damage to M-59, common construction risks, and additional exposure risks to potentially impacted ground water and soils. Although these additional exposure risks cannot be eliminated, they can be controlled through the use of appropriate health and safety guidelines during construction.

Other short-term risks that may be posed by the treatment system installation and operation include the possibility of a release of effluent air or water that will result in an unacceptable risk to human health or the environment. However, monitoring and proper controls on the effluent streams of the treatment system will minimize the potential for short-term risks associated with the operation of the system. Extracted ground water will be treated and discharged to adjacent surface waters following the substantive discharge requirements. Air discharges will be modelled, monitored, or treated as necessary to comply with the substantive clean air requirements for the State of Michigan.

5.5.6 Implementability

All aspects of Alternative 3A should be able to be implemented relatively easily. Technical implementation of the treatment system should be accomplished with no major difficulties. The resources and supplies needed for the placement of the extraction wells and the construction of the materials handling and treatment system equipment should be readily available. Institutional implementation would potentially require compliance with substantive requirements of air (State of Michigan) and surface water (NPDES) discharge permits prior to system operation. These issues should be able to be resolved with no significant difficulty. In addition, as mentioned for Alternative 2, deed restrictions could also be easily implemented; however, it would require the assistance of local government officials and Hi-Mill Manufacturing.

However, the implementation of an additional off-site ground-water extraction well for Alternative 3B could potentially be difficult. Construction of the single well and pipe system in the M-59 median would be technically feasible, but would require special traffic control along M-59. In addition, the remote off-site location of the extraction point would make connection with the on-site effluent treatment system difficult. The extracted ground water from this additional off-site well would have to be transported via force main beneath the northbound lanes of M-59 to the treatment system located on the facility property. The open trench construction in the median strip will require sheet piling to prevent collapse of the trench walls, and will require the use of additional personal protective equipment to protect against direct contact and inhalation of any constituents of concern that may be newly exposed by the trenching operation. Added to the difficulty of physically constructing such a pipeline is the administrative implementability issues of submitting designs and gaining approvals and permits from the Michigan Department of Transportation for construction within the median strip and trenching beneath the northbound lanes of M-59.

5.5.7 Costs

The costs associated with the implementation of Alternative 3A, rounded to the nearest $1,000, are $452,000 in capital costs and $134,000 in annual O&M costs for the first three years, followed by $73,000 in annual O&M cost for the next 27 years (see Table 7). The 30-year present net worth value of implementing Alternative 3A is therefore approximately $1,738,000.

The costs associated with the implementation of Alternative 3B, rounded to the nearest $1,000, are $564,000 in capital costs and $136,000 in annual O&M costs for the first three years, followed by $73,000 in annual O&M costs for the next 27 years (see Table 8). The 30-year present net worth value of implementing Alternative 3B is therefore approximately $1,857,000.

5.5.8 State Acceptance

The assessment of state acceptance can not be made until after the state provides its input to the USEPA's Proposed Plan.

5.5.9 Community Acceptance

The assessment of community acceptance can not be made until after completing the public comment period in which the public will have an opportunity to respond to the USEPA's Proposed Plan.

6.0 COMPARISON OF ALTERNATIVES

The previous sections presented the assessment of the individual alternatives against the nine evaluation criteria. To establish the relative advantages and disadvantages of the remedial alternatives a comparative analysis is performed in which all of the alternatives are evaluated against each of the evaluation criteria. The comparative analysis, the results of which are presented in this section, highlights the relative merits and drawbacks of the alternatives, and establishes what trade-offs exist between the various alternatives.

In comparing the alternatives, it must be noted that the March 8, 1993, NCP 40 CFR 300.430 (e)(9)(f), assigns relative levels of importance to the nine evaluation criteria. The relative levels of the evaluation criteria and their importance to the comparative analysis and selection of the preferred alternative, are presented below.

- Threshold Criteria: Overall protection of human health and the environment and compliance with ARARs, unless a specific ARAR is waived, are threshold requirements that each alternative must meet in order to be eligible for selection.

- Primary Balancing Criteria: Long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; implementability; and cost are the five primary balancing criteria. These primary balancing criteria are used to address the major trade-offs between the remedial alternatives.

- Modifying Criteria: State and community acceptance are modifying criteria which will be considered by the regulatory agencies in the selection of the final remedy. The impact of state and community acceptance in the remedy selection process will be addressed in the Record of Decision (ROD).

The results of the comparative analysis, in which all of the remedial alternatives are evaluated collectively against each of the evaluation criteria, are presented below. The comparative analyses are presented under the three levels of evaluation criteria.

6.1 THRESHOLD CRITERIA

Each alternative must meet both threshold criteria, unless a waiver is issued for a specific ARAR, in order to eligible for selection.

6.1.1 Overall Protection of Human Health and the Environment

In its present condition, the Hi-Mill site does not present a risk to human health and the environment, as determined by the baseline risk assessment (SEC Donohue 1992). The determination of the overall protection of human health and the environment provided by an alternative, thus, has to be made based on the degree to which the alternative would ensure the current risks to human health and the environment are not increased in the future. Based on the results of the baseline risk assessment, the key aspect of this determination is whether an alternative would be able to minimize or control future exposure to impacted ground water. This may be accomplished through the use of institutional controls to physically prevent exposure, or through the use of treatment technologies to reduce the harmful effects of any exposure by permanently reducing the mass (and, therefore, the concentration) of the constituents of concern within the ground water and soils.

Alternative 1 (No Action) would not ensure the overall protection of human health and the environment in the future since there would be no means to prevent, identify or mitigate any increased risks that could result from exposure to ground water in the future. The MDPH rules prohibiting the screening of a drinking water supply well within 25 ft bls would protect against such an exposure, but would not prevent the hypothetical future screening of a well into the shallow aquifer for landscape irrigation purposes. Although future exposure to impacted ground water from the impacted zone of the shallow aquifer for any reason is unlikely, the No Action alternative does not allow for the prevention of such an exposure, nor does it allow for the monitoring of the aquifer to detect possible lateral or vertical expansion of the ground-water plume.

The institutional controls provided under Alternative 2 would promote the continued protection of human health and the environment by controlling land and ground-water use. In addition, the implementation of Alternative 2 would also utilize ground-water monitoring to detect future constituent releases into the ground-water. As a result of the monitoring activities, appropriate additional remedial action could be taken, if necessary, to provide for the continued protection of human health and the environment in the event of a significant plume expansion.

Like Alternative 2, the active treatment alternatives (Alternatives 3A and 3B, vacuum enhanced recovery) would provide long-term protection of human health and the environment. In addition to the institutional controls provided in Alternative 2, Alternative 3A (on-site treatment configuration) utilizes the active treatment technologies of vacuum enhanced recovery, packed tower aeration, and catalytic oxidation (if necessary) to reduce the concentration of the constituents of concern in the ground water and soils. Alternative 3B (on and off-site treatment configuration) adds an off-site ground-water extraction well to the technologies listed for 3A, and thereby provides treatment to the outer reaches of the ground-water plume.

Based on the above discussion, all of the alternatives except Alternative 1 (No Action) would provide an acceptable degree of overall protection of human health and the environment.

6.1.2 Compliance with ARARs

Because of the absence of direct remedial activity for Alternative 1 and Alternative 2, no ARARs apply to these alternatives. A detailed analysis of the ARARs for the active treatment alternatives is presented in Table B-2 of Appendix B. Continued compliance with chemical-specific ARARs (e.g., MDNR Type C criteria) would be anticipated over the long term for Alternatives 3A and 3B. Assuming that the regulatory agencies would approve the necessary site activities for the alternatives, all of the alternatives would comply with the location-specific ARARs. All alternatives will also be implemented to comply with their respective action-specific ARARs.

6.2 PRIMARY BALANCING CRITERIA

The following primary balancing criteria are used to address the major trade-offs between the remedial alternatives. Because Alternative 1 (No Action) failed adequately meet the threshold criteria of overall protection of human health and the environment, the comparison of alternatives using the primary balancing criteria will not include the comparison to the No Action alternative.

6.2.1 Long-Term Effectiveness and Permanence

The institutional controls provided for Alternative 2 would provide long-term effectiveness and permanence in protecting human health and the environment while monitoring the progress of the natural degradation and attenuation of the constituents of concern within the ground water. Deed restrictions would prevent direct contact with, or ingestion of, impacted ground water in the future. In addition, ground-water monitoring would be a reliable means for determining if waste constituent releases were occurring in the future. This would allow for the future implementation of additional remedial controls, if necessary.

In addition to the controls afforded by Alternative 2, Alternatives 3A and 3B also incorporate ground-water and soils treatment as well as performance monitoring of the treatment systems employed. By employing vacuum enhanced recovery techniques to remove and treat the soil and ground water, Alternative 3A and 3B will further prevent the future potential exposure to unacceptable levels of constituents by controlling the migration of the constituents of concern. Nonetheless, the institutional controls portion of any active treatment remedy is the only means available to effectively prevent the potentially significant future exposure to the site materials prior to the reduction of the concentrations of the consituents of concern to risk-based levels.

Based on the modelling results, Alternative 3A will provide source control by controlling the flow of ground water from the site source areas. However, the additional potential benefits of accelerated aquifer restoration from Alternative 3A may be limited due to the questionable effectiveness of any aquifer restoration program operating under the complex hydrogeological constraints (e.g., discontinuous flow, low hydraulic conductivity, and thin saturated thickness) posed by the shallow ground-water unit. In the same way, the incremental added benefit of the off-site extraction well designed to accelerate the overall remediation of the shallow ground-water unit for Alternative 3B is difficult to assess. The additional benefits provided by the alternative may be insignificant compared to the additional implementation and short-term risk issues associated with implementation.

6.2.2 Reduction of Toxicity, Mobility or Volume through Treatment

Alternative 2 does not incorporate active treatment, and therefore would not reduce the mobility, the toxicity or the volume of the constituents of concern through treatment.

Alternative 2 does, however, provide for the monitoring of the passive biodegradation (if it should occur) and/or natural attenuation processes that will reduce the constituents of concern in the shallow aquifer.

Alternatives 3A and 3B do provide for the reduction of toxicity, mobility, and volume of the constituents of concern through the active treatment of the soils and ground water with the vacuum enhanced recovery technology along with diffused aeration and treatment of air emissions (if necessary). Alternative 3A will treat all of the impacted soils and control the source of the impacted ground water at the site. In addition to the treatment controls provided by Alternative 3A, Alternative 3B provides for the treatment of down-gradient (off-site) ground water in the M-59 median strip.

6.2.3 Short-Term Effectiveness

Alternative 2 would provide a relatively high degree of short-term effectiveness because no disturbance of the impacted soils or ground-water occur during implementation of the deed restrictions, and limited contact with potentially impacted soils and ground water during the installation of the additional ground-water monitoring wells.

Alternative 3A would provided a relatively lower level of short-term effectiveness than Alternative 2 because of the additional potential exposure risks that would be realized during the construction of the extraction wells and operation of the treatment system. Alternative 3B would provide the lowest level of short-term effectiveness and would present the highest level of short-term risks associated with any of the alternatives due to the added construction and exposure risks associated with the construction of the effluent force main under the north bound lanes of M-59. these short-term risks cannot be eliminated, they can be controlled through appropriate health and safety practices.

6.2.4 Implementability

The institutional controls provided for Alternative 2 (and also included as part of the other alternatives) could all be readily implemented. The additional components necessary for the implementation of Alternative 3A, although more difficult to implement than the institutional controls, could also be constructed rather easily. Alternative 3B would be the most difficult alternative to implement, primarily because of the trenching and installation of associated piping necessary to transport the extracted off-site ground water to the on-site treatment system. This would pose both technical and administrative implementability difficulties due to the necessity to pipe the extracted ground water from the M-59 median to the ground-water treatment system located on the Hi-Mill site. This would involve construction of an underground force main that would run under the north bound lanes of Michigan highway M-59.

6.2.5 Costs

Apart from the No Action Alternative, Alternative 2 had the lowest present net worth cost of all the alternatives at $565,000. This was followed by Alternative 3A at $1,738,000, and Alternative 3B at $1,857,000.

6.3 MODIFYING CRITERIA

These criteria may be utilized to modify the final remedy based on state and community acceptance.

6.3.1 State Acceptance

The determination of which alternative or alternatives would be acceptable to the state cannot be made until after the state provides its input to the USEPA's Proposed Plan.

6.3.2 Community Acceptance

The determination of which alternative or alternatives would be acceptable to the community cannot be made until after completing the public comment period in which the public will have an opportunity to respond to the USEPA's Proposed Plan.

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TABLES

Table 1. Generic ARARs for Potable Water Supply Wells and Soils, Hi-Mill Manufacturing Company, Highland, Michigan.

COCs	Ground Water SDWA MCLs (mg/L)	Ground Water Michigan Act 307 Type B Criteria (mg/L)	Soils Michigan Act 307 Type B DC (mg/kg)	Soils Michigan Act 307 Type B 20xGW (mg/kg)
VOCs				
Bromodichloromethane	0.1 a	0.0003	3	0.006
1,2-Dichloroethene	0.07 b	NA	NA	NA
Trichloroethene	0.005	0.003	40	0.06
Vinyl Chloride	0.002	0.00002	0.2	0.0004
Inorganics				
Antimony	0.006	0.003	100	0.05
Arsenic	0.05	0.00002	0.8	0.0004
Beryllium	0.004	NA	NA	NA
Nitrate/Nitrite	10/1	10/0.7	40,000/3,000	200/14

a based on standard for total trihalomethanes.
b based on standard for cis-1,2-dichloroethene.
SDWA Safe Drinking Water Act
MCLs Maximum Contaminant Levels
DC direct contact exposure-based criteria
20xGW soil criteria based on 20 times ground-water criteria
VOCs volatile organic compounds
mg/L milligrams per liter
mg/kg milligrams per kilogram
NA not available

Table 2. Equations for Risk-Based Cleanup Levels for a Hypothetical Future Site Worker Exposed to Ground Water, Hi-Mill Manufacturing Company, Highland, Michigan.

$$GWCL\ (mg/L) = \frac{TR \times BW \times AT}{EF \times ED \times ET \times ([RSDo \times IR] + [RSDa \times SSA \times PC \times UCF])}$$

where:

AT	Averaging time for carcinogenic effects, 25550 day (70 years x 365 days/year), and 9,125 days (ED x 365 days/year) for non-cancer effects.
BW	Adult body weight, 70 kg.
cm	Centimeters
CSFa	Adjusted dermal cancer slope factor, constituent-specific (kg-day/mg).
CSFo	Oral cancer slope factor, constituent-specific (kg-day/mg).
ED	Exposure duration, 25 years
EF	Exposure frequency, 17 days/year.
ET	Exposure time, 1 hour/day.
GWCL	Ground-water cleanup level, mg/L.
IR	Incidental water ingestion rate, 0.005 L/hour.
kg	Kilograms.
L	Liter.
mg	Milligrams.
PC	Permeability constant, cm/hr, constituent-specific
RfDa	Adjusted reference does, (mg/kg/day).
RfDo	Oral reference dose (mg/kg/day).
RSDa	Adjusted risk-specific dose, CSFa for cancer, and 1/RfDa for non-cancer.
RSDo	Oral risk-specific dose, CSFo for cancer, and 1/RfDo for non-cancer.
SSA	Skin surface area, 9,350 cm^2.
TR	Target risk level of 1E-06 for cancer and 1 for non-cancer.
UCF	Unit conversion factor, 0.001 L/cm^3.
yr	Year.

Sample calculation of cancer risk-based GWCL for trichloroethene in ground-water:

$$GWCL = \frac{0.000001 \times 70\ kg \times 25550\ days}{17\ days/yr \times 25\ yrs \times 1\ hr/day \times ([0.011\ kg\text{-}day/mg \times 0.005\ L/hour] + [0.011\ kg\text{-}day/mg \times 9{,}350\ cm^2 \times 0.2\ cm/hour \times 0.001\ L/cm^3])}$$

GWCL = 0.20 mg/L

Reference: USEPA, 1991a.

Table 3. Risk-Based Cleanup Levels for an Industrial Site Worker for Exposure to COCs in Ground Water
Hi-Mill Manufacturing Company, Highland, Michigan

COCs	PC (cm/hour)	CSFo (kg-day/mg)	CSFa (kg-day/mg)	RfDo (mg/kg/mg)	RfDa (mg/kg/mg)	Cancer Effects GWCL (mg/L)	Non-Cancer Effects GWCL (mg/L)	GWCL (mg/L)
<u>VOCs</u>								
Bromodichloromethane	5.8E-03	1.3E-01	1.3E-01	2.0E-02	2.0E-02	0.55	510	0.55
1,2-Dichloroethene	1.0E-02	NC	NC	9.0E-03	9.0E-03	NC	140	140
Trichloroethene	2.0E-01	1.1E-02	1.1E-02	NA	NA	0.20	NA	0.20
Vinyl Chloride	7.3E-03	1.9E+00	1.9E+00	NA	NA	0.03	NA	0.03
<u>Inorganics</u>								
Antimony	1.0E-03	NC	NC	4.0E-03	4.0E-05	NC	6.4	6.4
Arsenic	1.0E-03	1.75E+00	1.8E+00	3.0E-04	2.9E-04	0.16	30	0.16
Beryllium	-	4.3E+00	-	5.0E-03	-	0.20	2,000	0.20
Nitrate/Nitrite	1.0E-03	NC	NC	1.0E-01	1.0E-01	NC	10,000	10,000

cm/hour	Centimeters per hour.
CSFa	Adjusted cancer slope factor, kg-day/mg.
CSFo	Oral cancer slope factor, kg-day/mg.
GWCL	Ground-water cleanup level, lesser concentration of non-carcinogenic effects and carcinogenic effects, mg/L.
kg-day/mg	Kilograms-day per milligram.
mg/kg/day	Milligrams per kilogram per day.
mg/L	Milligrams per liter.
NA	Not available.
NC	Not carcinogenic.
PC	Permeability constant, cm/hour.
RfDa	Adjusted reference dose, mg/kg/day.
RfDo	Oral reference dose, mg/kg/day.

Table 4. Leachability-Based Soil Cleanup Levels
Hi-Mill Manufacturing Company, Highland, Michigan

COCs	Cgw (mg/L)	Koc (ml/g)	Kd (ml/g)	Cs (mg/kg)
VOCs				
Bromodichloromethane	0.55	62	0.62	0.43
1,2-Dichloroethene	140	59	0.59	110
Trichloroethene	0.20	126	1.26	0.32
Vinyl chloride	0.030	2.5	0.025	0.00096
Inorgancis				
Antimony	6.4	-	45	370
Arsenic	0.16	-	200	41
Beryllium	0.20	-	650	170
Nitrate/Nitrite	10,000	-	0.01	130

Equation definitions:

$$Cs = Kd \times [Cgw \times [Qp + Qa])/Qp]$$
$$Kd = Koc \times Foc$$

Where:		
	Cgw	Ground-water PRG (mg/L);
	Cs	Soil concentration protective of ground water (mg/kg);
	Foc	Fraction organic carbon (0.01);
	Kd	Soil/water partition coefficient (ml/g);
	Koc	Organic carbon partition coeffcient (ml/g);
	Qa	Volumetric flow rate of ground water (56.4 ft^3/day);
	Qp	Infiltration due to precipitation (205 ft^3/day).
	ft^3/day	Cubic feet per day.
	kg	Kilograms.
	L/day	Liters per day.
	ml/g	Milliliters per gram.
	mg/kg	Milligrams per kilogram.
	mg/L	Milligrams per liter.

Table 5. Generic and Site-Specific (Risk-Based) ARARs for Ground Water and Soils, Hi-Mill Manufacturing Company, Highland, Michigan.

COCs	Generic ARARs GW (mg/L)	Generic ARARs Soils (mg/kg)	Site-Specific ARARs GW (mg/L)	Site-Specific ARARs Soils (mg/kg)
VOCs				
Bromodichloromethane	0.0003	0.006	0.55	0.43
1,2-Dichloroethene	0.07	NA	140	110
Trichloroethene	0.003	0.06	0.20	0.32
Vinyl Chloride	0.00002	0.0004	0.030	0.00096
Inorganics				
Antimony	0.003	0.05	6.4	370
Arsenic	0.00002	0.0004	0.16	41
Beryllium	0.004	NA	0.20	170
Nitrate/Nitrite	10/0.7	200/14	10,000	130

ARAR Applicable or relevant and appropriate requirements
VOCs Volatile Organic Compounds
mg/L milligrams per liter
mg/kg milligrams per kilogram
NA not available

Table 6. Cost Estimate for Alternative 2, Institutional Controls, Hi-Mill Manufacturing Company, Highland, Michigan.

CONSTRUCTION COST ELEMENT	UNIT COST	UNIT	UNITS REQ'D	SUBTOTAL
NEW MONITORING WELLS				
Mobilization/Demobilization	3,500	ls	1	$3,500
Drilling Oversight	12,000	ls	1	12,000
Well Installation	1,500	well	6	9,000
	Construction Cost Subtotal			$24,500
CONTINGENCIES				
Scope Contingency (10%)				2,450
Bid Contingency (10%)				2,450
Health & Safety (5%)				1,225
	Total Construction Costs			$30,625
INDIRECT CAPITAL COSTS				
Permitting and Legal				5,000
	Total Capital Costs			$35,625

ANNUAL O&M COSTS (YEARS 1-3)	Unit Price	Unit	Units Req'd	Subtotal
Quarterly Ground-Water Monitoring	$21,700	event	4	$86,800
Project Management	100	month	12	1200
	Annual O&M Costs (Years 1-3)			$88,000

ANNUAL O&M COSTS (YEARS 4-30)	Unit Price	Unit	Units Req'd	Subtotal
Annual Ground-Water Monitoring	$21,700	event	1	$21,700
Project Management	100	month	12	1200
	Annual O&M Costs (Years 4-30)			$22,900

Table 6. Cost Estimate for Alternative 2, Institutional Controls, Hi-Mill Manufacturing Company, Highland, Michigan.

PRESENT NET WORTH (PNW) ANALYSIS

Total Capital Cost	$35,625
PNW of O&M (Years 1-3)	$239,624
PNW of O&M (Years 4-30)	$289,662
Total 30 Year PNW	$564,911

Assumptions:
1. A total of 19 monitoring wells will be sampled per event.
2. Ground-water samples will be analyzed for Target Compound List (TCL) VOCs.
3. Permitting and legal costs assume routine access for installation of off-site wells.
4. PNW of O&M is based on a 5% discount rate.

Table 7. Cost Estimate for Alternative 3A, On-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

CONSTRUCTION COST ELEMENT	UNIT COST	UNIT	UNITS REQ'D	SUBTOTAL
GENERAL				
Mobilization/Demobilization	$3,500	ls	1	$3,500
Field Office	1,000	ls	1	1,000
SITE WORK				
Site Preparation	2,000	ls	1	2,000
Surveying	1,200	ls	1	1,200
RECOVERY WELLS & FORCE MAIN				
Vacuum-Enhanced Design Test	23,000	ls	1	23,000
Drilling Oversight - RW's	5,000	ls	1	5,000
Well Installation - RW's	1,100	well	8	8,800
Well Head Installation	2,000	well	8	16,000
Saw Cutting Pavement	2	lf	500	1,000
Concrete/Asphalt Removal	4	sf	250	1,000
Force Main to Treatment Facility	25	ft	1,125	28,125
Valves & Gauges	150	well	8	1,200
Manifold Construction	2,300	ls	1	2,300
Heat Trace & Insulate	1,500	well	8	12,000
Resurfacing	10	sf	500	5,000
Pea Gravel Backfill	50	cy	20	1,000
Disposal - Concrete/Asphalt	2,000	ls	1	2,000
TREATMENT FACILITY				
Modular System: vacuum-enhanced module, D4 diffuser, o/w sep, product storage drum liquid and vapor phase carbon, skid-mounted enclosure (8'x22') with xp controls, xp lighting and heating	135,000	ls	1	135,000
Additional freeze protection	3,000	ls	1	3,000
In-line heater for vapor phase carbon	5,000	ls	1	5,000
Telemetry (auto-dialer)	5,000	ls	1	5,000
Concrete Pad (15' x 20')	2,250	ls	1	2,250
Chain-link Fence	20	lf	70	1,400
Discharge Pipe Installation	20	lf	500	10,000
Electrical	10,000	ls	1	10,000
			Construction Cost Subtotal	$285,775

Table 7. Cost Estimate for Alternative 3A, On-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

CONTINGENCIES				
Scope Contingency (10%)				$28,578
Bid Contingency (10%)				28,578
Health & Safety (5%)				14,289
			Total Construction Costs	$357,219
INDIRECT CAPITAL COSTS				
Engineering (15%)				53,583
Construction Management (10%)				35,722
Permitting and Legal				5,000
			Total Capital Costs	$451,523

ANNUAL O&M COSTS (YEARS 1-3)	Unit Price	Unit	Units Req'd	Subtotal
Quarterly Ground-Water Monitoring	$20,600	event	4	$82,400
Vapor-Phase Carbon Replacement	2	pound	7,500	15,000
Liquid-Phase Carbon Replacement	2	pound	200	400
Treated Effluent Analytical Costs	300	sample	12	3,600
Air Emissions Analytical Costs	250	sample	12	3,000
Electricity	1,500	month	12	18,000
Routine Maintenance	500	month	12	6,000
Potable Water Use	150	month	12	1,800
Project Management	360	month	12	4,320
			Annual O&M Costs (Years 1-3)	$134,520

ANNUAL O&M COSTS (YEARS 4-30)	Unit Price	Unit	Units Req'd	Subtotal
Annual Ground-Water Monitoring	$20,600	event	1	$20,600
Vapor-Phase Carbon Replacement	2	pound	7,500	15,000
Liquid-Phase Carbon Replacement	2	pound	200	400
Treated Effluent Analytical Costs	300	sample	12	3,600
Air Emissions Analytical Costs	250	sample	12	3,000
Electricity	1,500	month	12	18,000
Routine Maintenance	500	month	12	6,000
Potable Water Use	150	month	12	1,800
Project Management	360	month	12	4,320
			Annual O&M Costs (Years 4-30)	$72,720

Table 7. Cost Estimate for Alternative 3A, On-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

PRESENT NET WORTH (PNW) ANALYSIS

Total Capital Costs	$451,523
PNW of O&M (Years 1-3)	$366,298
PNW of O&M (Years 4-30)	$919,835
Total 30 Year PNW	$1,737,657

Assumptions:

1. 2 gpm maximum combined recovery rate for 8 extraction wells
2. Treatment enclosure located on Hi-Mill property
3. Iron removal will be provided by air diffuser
4. 460 volt power available on-site within 100 feet of enclosure
5. 110 volt power within 300 feet of each well head
6. Potable water available within 100 feet of treatment enclosure
7. Treatment of VOCs to 5ppb (vinyl chloride to 3 ppb)
8. Effluent discharge to N. Arm Waterbury Lake
9. Assume $2.00/1000 gallons potable water
10. Disposal of collected product will be to existing storage tank on-site or by an existing recycling contractor
11. 1.25" Sch 80 PVC Recovery Pipe
12. Vacuum-enhanced design testing of three wells (12 hrs. each) does not include well installation and oversight
13. Electrical operation cost estimated to be $1,500 per month.
14. Well head installation includes well head, well vault and materials
15. PNW of O&M is based on a 5% discount rate.

Table 8. Cost Estimate for Alternative 3B, On-Site/ Off-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

CONSTRUCTION COST ELEMENT	UNIT COST	UNIT	UNITS REQ'D	SUBTOTAL
GENERAL				
Mobilization/Demobilization	$3,500	ls	1	$3,500
Field Office	1,000	ls	1	1,000
SITE WORK				
Site Preparation	2,000	ls	1	2,000
Surveying	1,200	ls	1	1,200
RECOVERY WELLS & FORCE MAIN (ON-SITE)				
Vacuum-Enhanced Design Test	23,000	ls	1	23,000
Drilling Oversight - RW's	5,000	ls	1	5,000
Well Installation - RW's	1,100	well	8	8,800
Well Head Installation	2,000	well	8	16,000
Saw Cutting Pavement	2	lf	500	1,000
Concrete/Asphalt Removal	4	sf	250	1,000
Force Main to Treatment Facility	25	ft	1125	28,125
Valves & Gauges	150	well	8	1,200
Manifold Construction	2,300	ls	1	2,300
Heat Trace & Insulate	1,500	well	8	12,000
Resurfacing	10	sf	500	5,000
Pea Gravel Backfill	50	cy	20	1,000
Disposal - Concrete/Asphalt	2,000	ls	1	2,000
RECOVERY WELL & FORCE MAIN (OFF-SITE)				
Horizontal Boring	30,000	ls	1	30,000
Drilling Oversight - RW's	1,000	ls	1	1,000
Well Installation - RW's	1,100	well	1	1,100
Well Head Installation	1,500	well	1	1,500
Force Main to Treatment Facility	25	lf	500	12,500
Valves & Gauges	125	well	1	125
Manifold Construction	500	ls	1	500
Heat Trace & Insulate	1,500	well	1	1,500
Pea Gravel Backfill	50	cy	20	1,000
Disposal - Concrete/Asphalt	1,000	ls	1	1,000
TREATMENT FACILITY				
Modular System: vacuum-enhanced module, D4 diffuser, liquid and vapor phase carbon, o/w sep, product storage drum, skid mounted enclosure (8'x22') with	135,000	ls	1	135,000

Table 8. Cost Estimate for Alternative 3B, On-Site/ Off-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

xp controls, xp heater, xp lighting				
Additional freeze protection	3,000	ls	1	3,000
In-line heater for vapor phase carbon	5,000	ls	1	5,000
Telemetry (auto-dialer)	5,000	ls	1	5,000
Concrete Pad (15' x 20')	2,250	ls	1	2,250
Chain-link Fence	20	lf	70	1,400
Discharge Pipe Installation	20	lf	500	10,000
Electrical	12,500	ls	1	12,500
		Construction Cost Subtotal		$338,500
CONTINGENCIES				
Scope Contingency (10%)				$33,850
Bid Contingency (10%)				33,850
Health & Safety (5%)				16,925
		Total Construction Costs		$423,125
INDIRECT CAPITAL COSTS				
Engineering (15%)				63,469
Construction Management (10%)				42,313
Permitting and Legal				35,000
		Total Capital Costs		$563,906

ANNUAL O&M COSTS (YEARS 1-3)	Unit Price	Unit	Units Req'd	Subtotal
Quarterly Ground-Water Monitoring	$20,900	event	4	$83,600
Vapor-Phase Carbon Replacement	2	pound	7,500	15,000
Liquid-Phase Carbon Replacement	2	pound	200	400
Treated Effluent Analytical Costs	300	sample	12	3,600
Air Emissions Analytical Costs	250	sample	12	3,000
Electricity	1,500	month	12	18,000
Routine Maintenance	500	month	12	6,000
Potable Water Use	150	month	12	1,800
Project Management	360	month	12	4,320
		Annual O&M Costs (Years 1-3)		$135,720

Table 8. Cost Estimate for Alternative 3B, On-Site/ Off-Site Vacuum Enhanced Recovery, Hi-Mill Manufacturing Company, Highland, Michigan.

ANNUAL O&M COSTS (YEARS 4-30)	Unit Price	Unit	Units Req'd	Subtotal
Annual Ground-Water Monitoring	$20,900	event	1	$20,900
Vapor-Phase Carbon Replacement	2	pound	7,500	15,000
Liquid-Phase Carbon Replacement	2	pound	200	400
Treated Effluent Analytical Costs	300	sample	12	3,600
Air Emissions Analytical Costs	250	sample	12	3,000
Electricity	1,500	month	12	18,000
Routine Maintenance	500	month	12	6,000
Potable Water Use	150	month	12	1,800
Project Management	360	month	12	4,320
		Annual O&M Costs (Years 4-30)		$73,020

PRESENT NET WORTH (PNW) ANALYSIS

Total Capital Costs	$563,906
PNW of O&M (Years 1-3)	$369,566
PNW of O&M (Years 4-30)	$923,630
Total 30 Year PNW	$1,857,102

Assumptions:
1. 2 gpm maximum combined recovery rate for 8 extraction wells
2. Treatment enclosure located on Hi-Mill property
3. Iron removal will be provided by air diffuser
4. 460 volt power available on-site within 100 feet of enclosure
5. 110 volt power 300 feet of each well head
6. Potable water available within 100 feet of treatment enclosure
7. Treatment of VOCs to 5ppb (vinyl chloride to 3ppb)
8. Effluent discharge to N. Arm of Waterbury Lake
9. Assume $2.00/1000 gallons potable water
10. Disposal of collected product will be to existing storage tank on-site or by an existing recycling contractor
11. 1.25" Sch 80 PVC Recovery Pipe
12. Vacuum-enhanced design testing of three wells (12 hrs. each) does not include well installation and oversight co
13. Electrical operation cost estimated to be $1,500 per month
14. Well head installation includes well head and well vault
15. PNW of O&M is based on a 5% discount rate.

FIGURES

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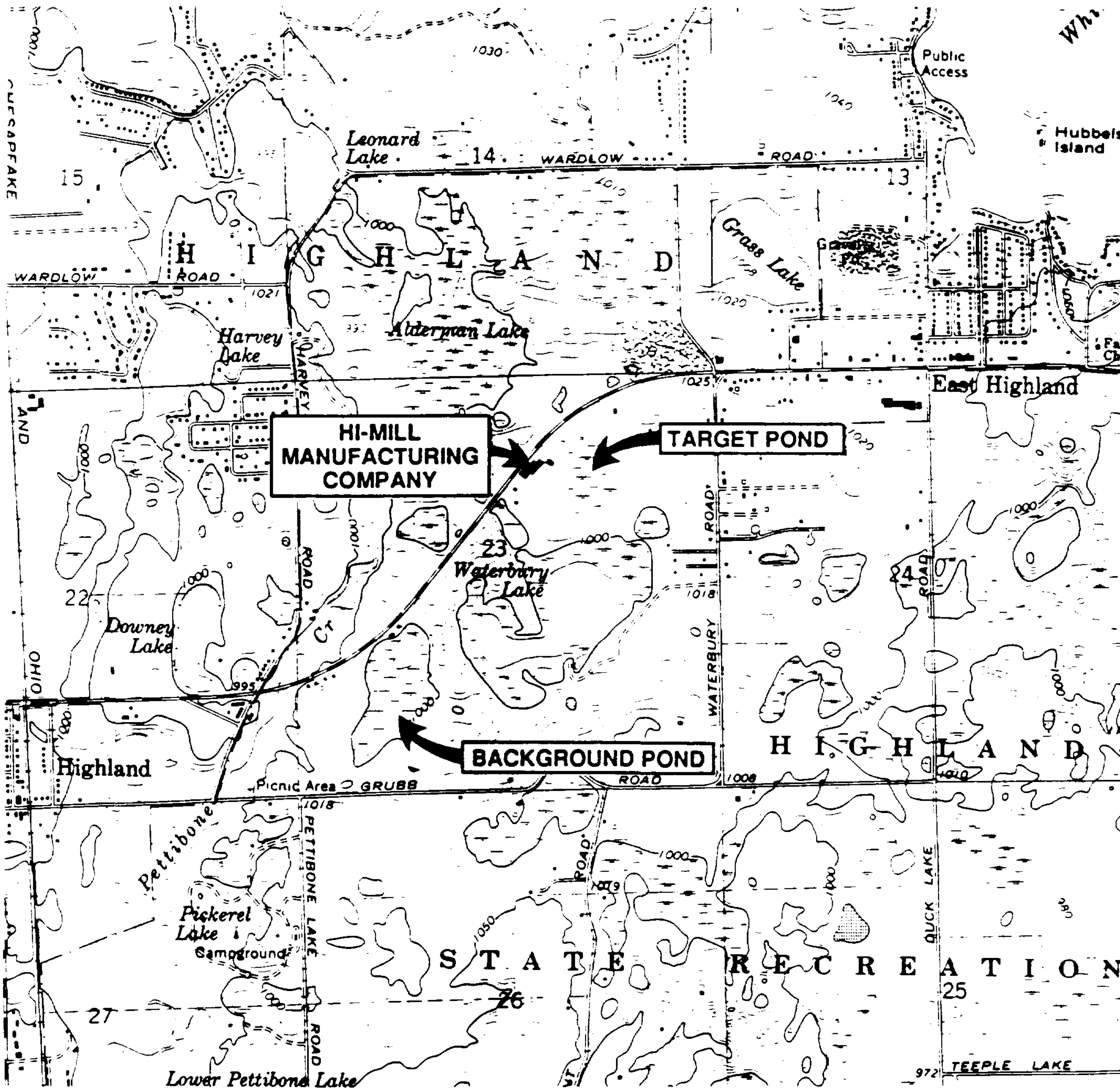
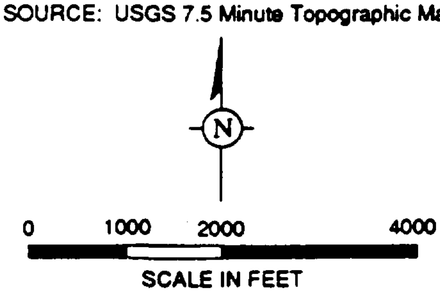
APPROVED: JJ
CHECKED: SE
DRAWING: 01
FILE NO.: 96
PRJCT NO.: MI319.02
DWG DATE: 02APR93



SOURCE: USGS 7.5 Minute Topographic Map, HIGHLAND, MICHIGAN Quadrangle, 1983

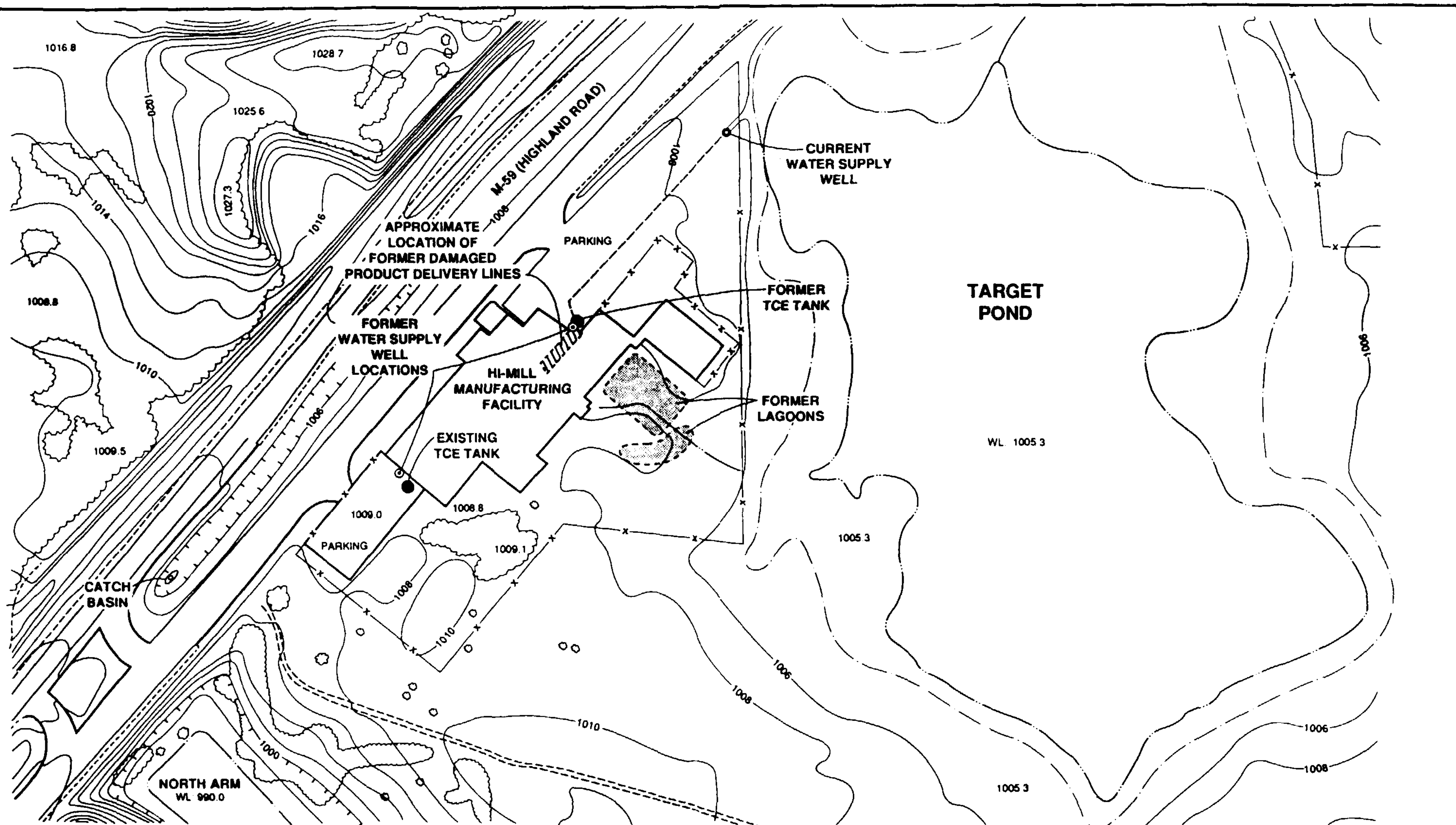


GERAGHTY & MILLER, INC.
Environmental Services

SITE LOCATION

HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

FIGURE
1



REFERENCE: ABRAMS AERIAL SURVEY, 1989.

NOTE: ALL ELEVATIONS REPORTED IN FT. MSL.

N

0 125 250

SCALE IN FEET

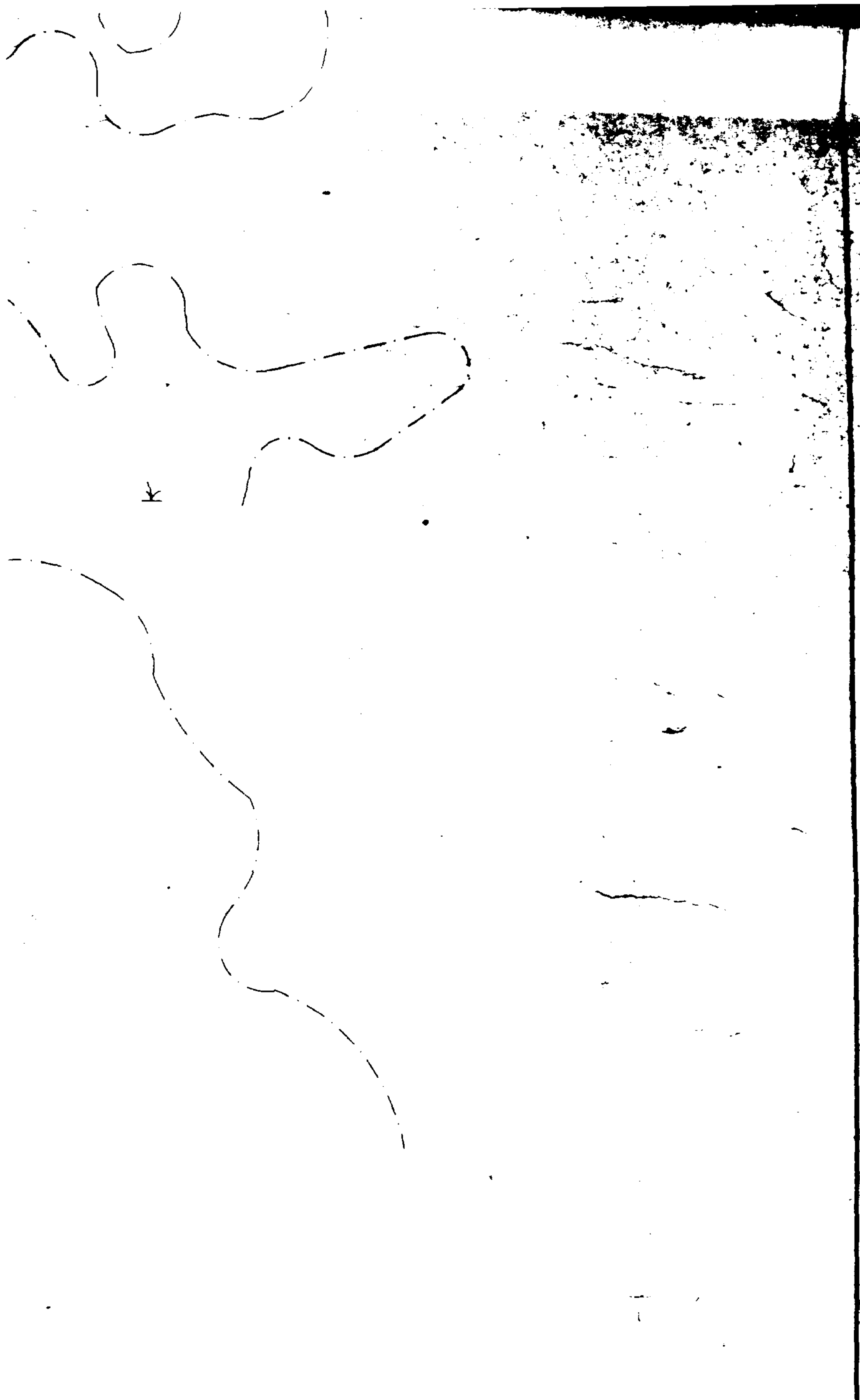
GERAGHTY & MILLER, INC.
Environmental Services

SITE TOPOGRAPHY AND PHYSICAL FEATURES

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

FIGURE 2

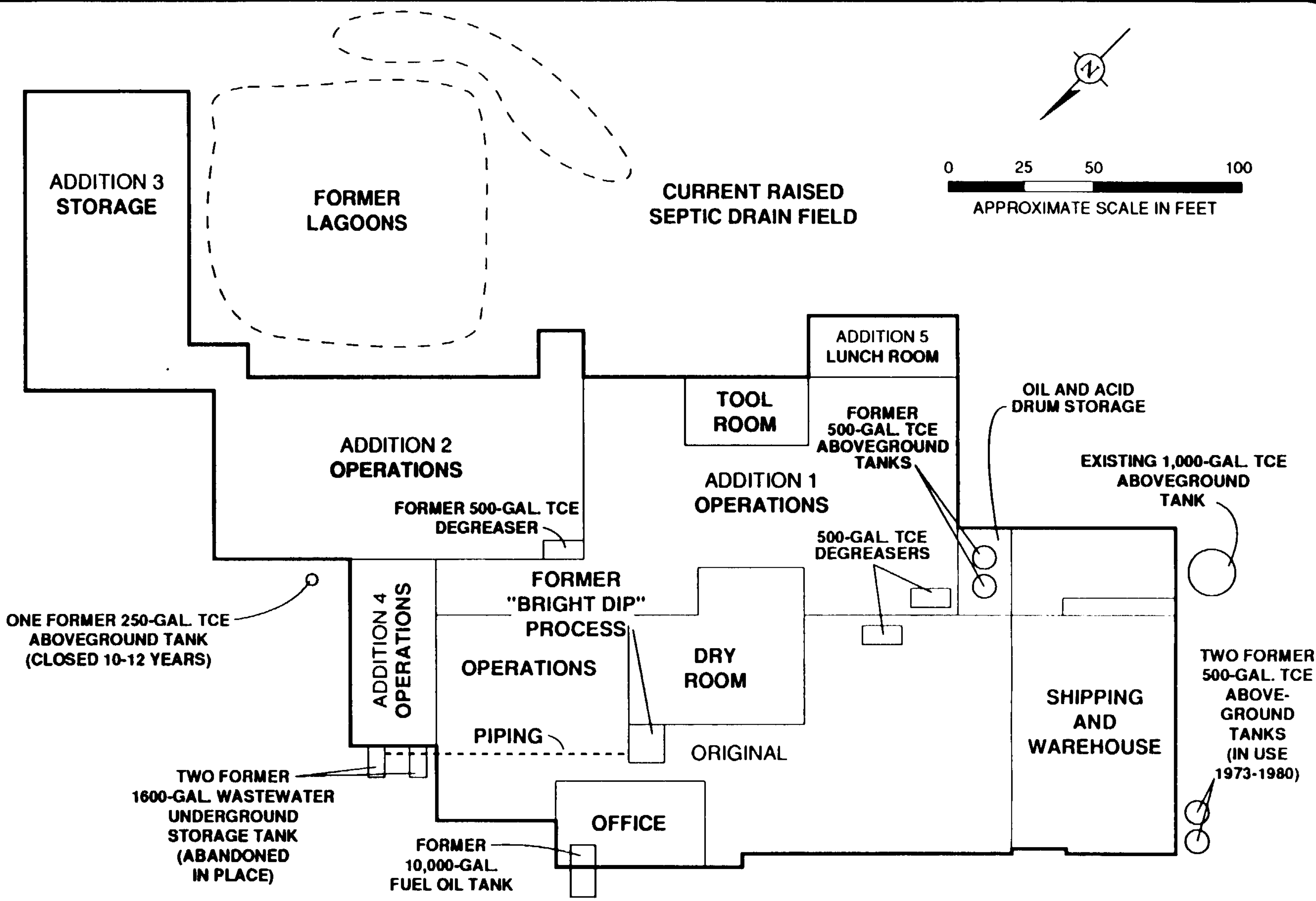
DWG DATE: 02APR93 | PRJCT NO.: MI319.02 | FILE NO.: 96 | DRAWING: 02 | CHECKED: RS | APPROVED: JJ | DRAFTER: MS



BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

RIBUTION OF VOLATILE ORGANIC COMPOUNDS IN GROUND-WATER AND SOIL REMEDIAL INVESTIGATION/FEASIBILITY STUDY HI-MILL MANUFACTURING HIGHLAND, MICHIGAN	FIGURE 3

DWG DATE: 02APR93	PRJCT NO.: MI319.02	FILE NO.: 96	DRAWING: 06	CHECKED: RS	APPROVED: JJ	DRAFTER: MS

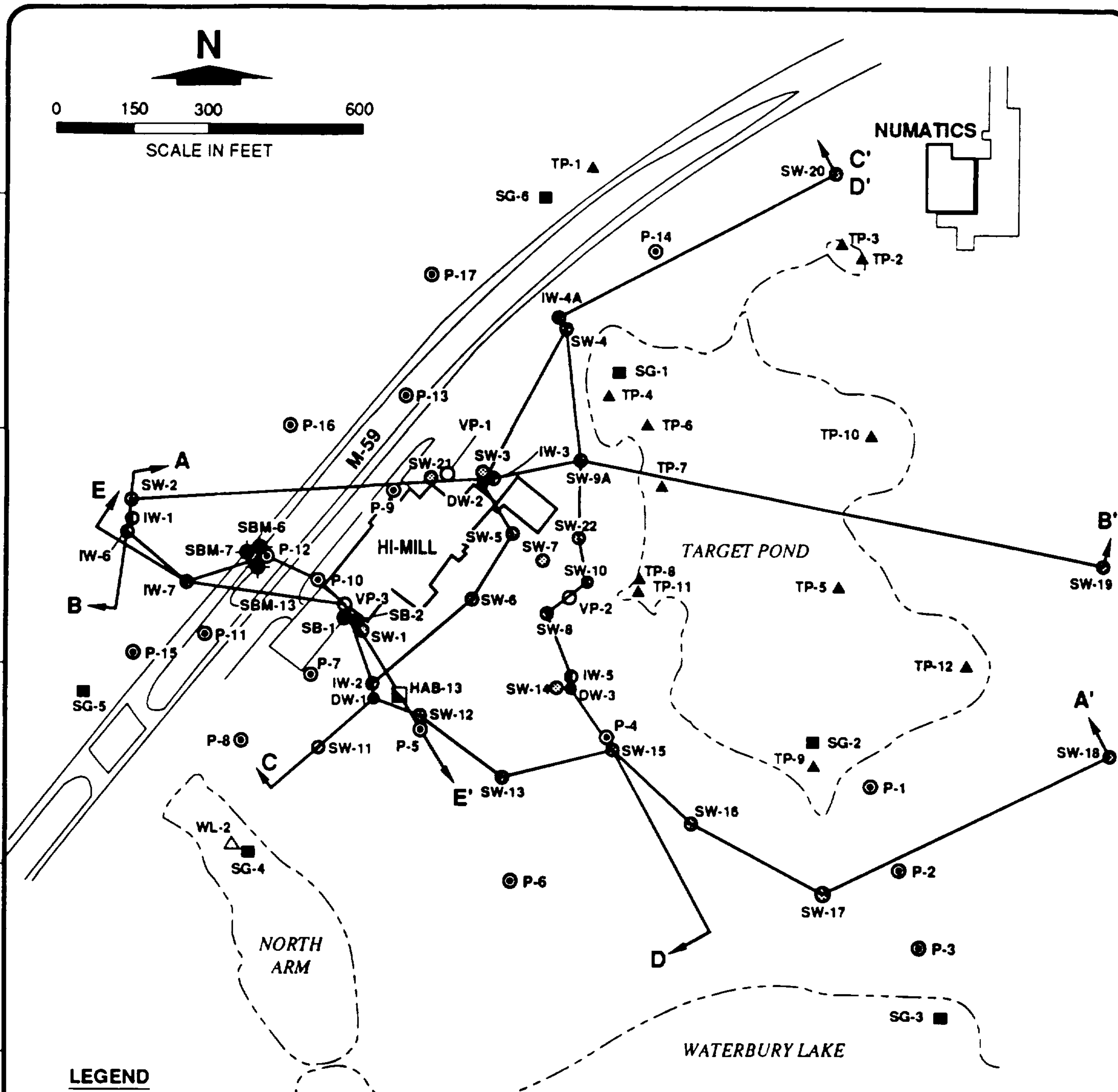


GERAGHTY & MILLER, INC.
Environmental Services

MAIN MANUFACTURING PLANT DIAGRAM

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE
4



LEGEND

APPROXIMATE LOCATIONS	
SW-1 SHALLOW MONITORING WELL	TP-1 TARGET WETLAND (POND) SAMPLE
IW-1 INTERMEDIATE MONITORING WELL	WL-2 WATERBURY LAKE SAMPLE
DW-1 DEEP MONITORING WELL	P-6 PIEZOMETER LOCATION
SG-1 STAFF GAUGE	VP-1 VERTICLE PROFILE BORING
SB-1 SOIL BORING	HAB-13 HAND AUGER BORING
	SBM-7 MEDIAN SOIL BORING

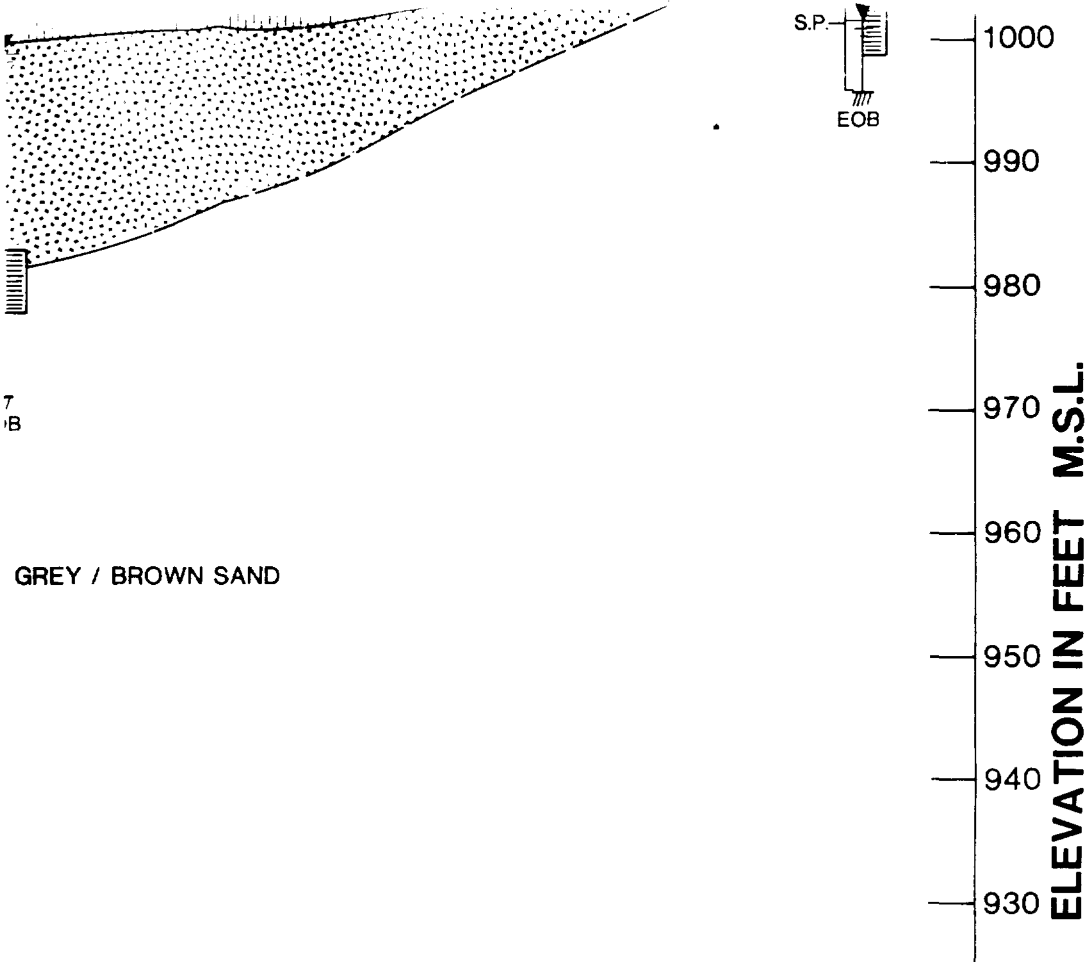
GERAGHTY & MILLER, INC.
Environmental Services

GEOLOGIC CROSS-SECTION LOCATIONS

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 5

DRAFTER: MS | APPROVED: JJ | CHECKED: RS | DRAWING: 10 | FILE NO.: 96 | PRJCT NO.: MI319.02 | DWG DATE: 02APR93



GEND

LITHOLOGIC CONTACT
DASHED WHERE INFERRED
QUERIED (?) WHERE UNCERTAIN

FILL

BROWN SAND

BROWN SILTY SAND

BROWN / GREY VARIEGATED SILTY CLAY

GREY SAND & SILT

BROWN SILT & SAND

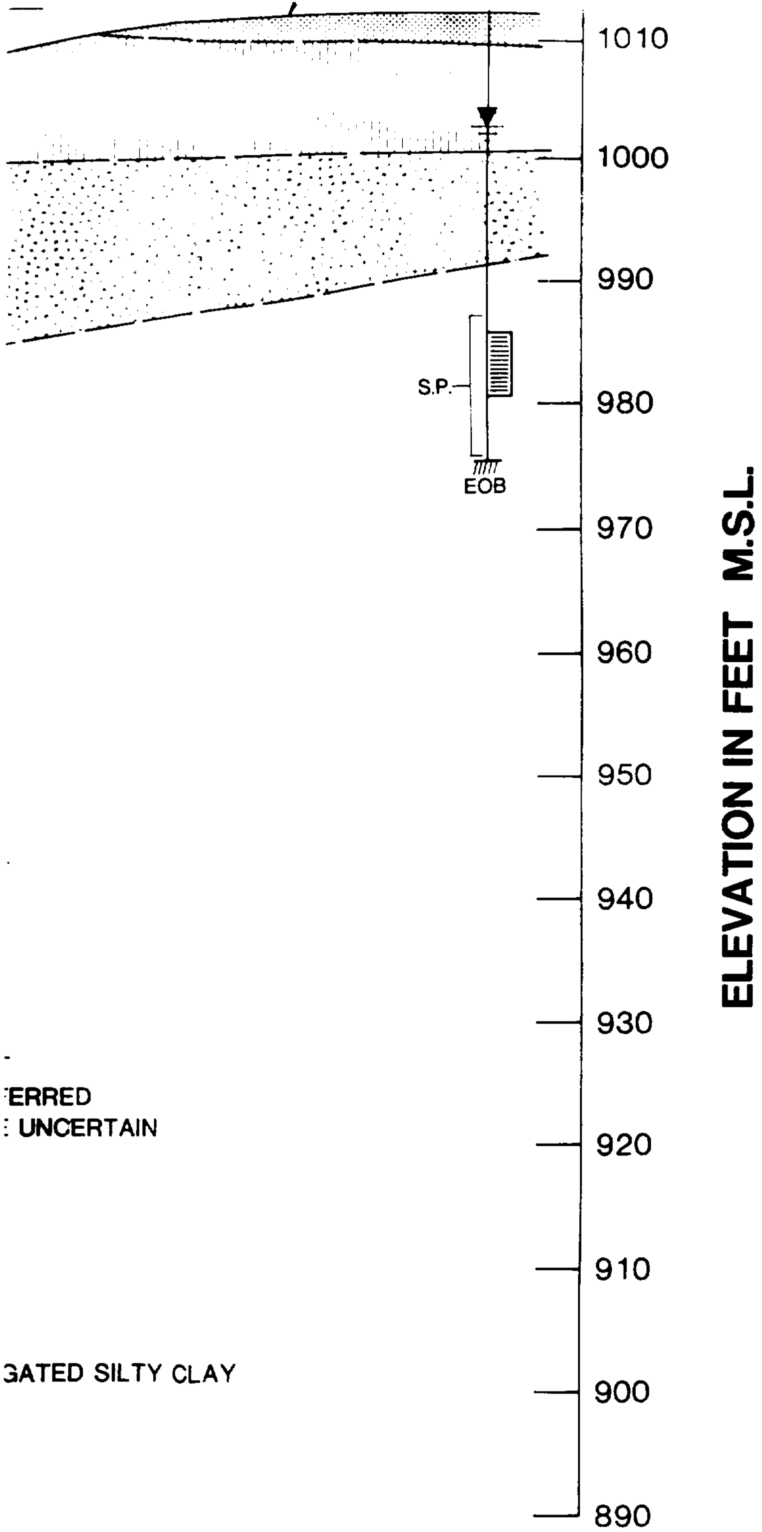
GREY / BLUE SILTY CLAY

HOWN — GREY / BROWN SAND

GREY SILT

GREY CLAYEY SILT

FILE NO: NON-CAD PLOT SIZE: DATE: DATE: DATE:	**GEOLOGIC CROSS SECTION A-A'** REMEDIAL INVESTIGATION / FEASIBILITY STUDY HI-MILL MANUFACTURING COMPANY	FIGURE **6**



ERRED
UNCERTAIN

GATED SILTY CLAY

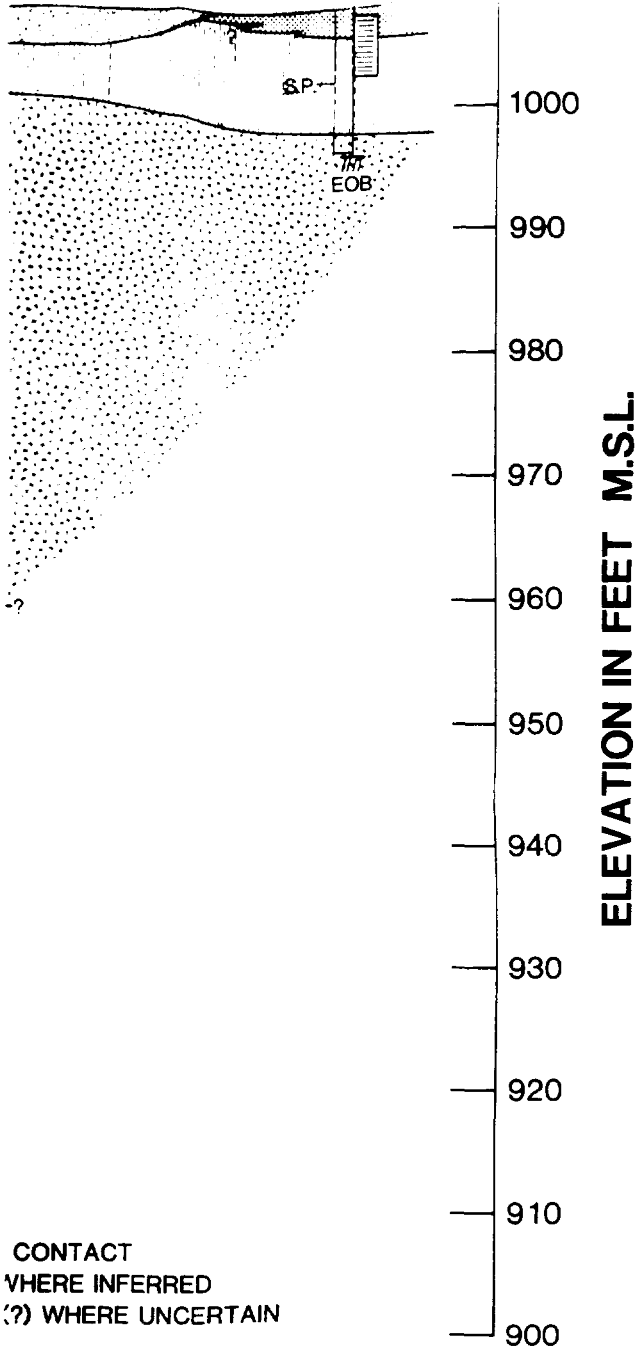
AY

NO: NON-CAD
SIZE:

GEOLOGIC CROSS SECTION B-B'

REMEDIAL INVESTIGATION / FEASIBILITY STUDY
HI-MILL MANUFACTURING COMPANY

FIGURE
7



CONTACT
VHERE INFERRED
(?) WHERE UNCERTAIN

(SAND

(VARIEGATED SILTY CLAY

: SILTY CLAY

WN SAND

:Y SILT

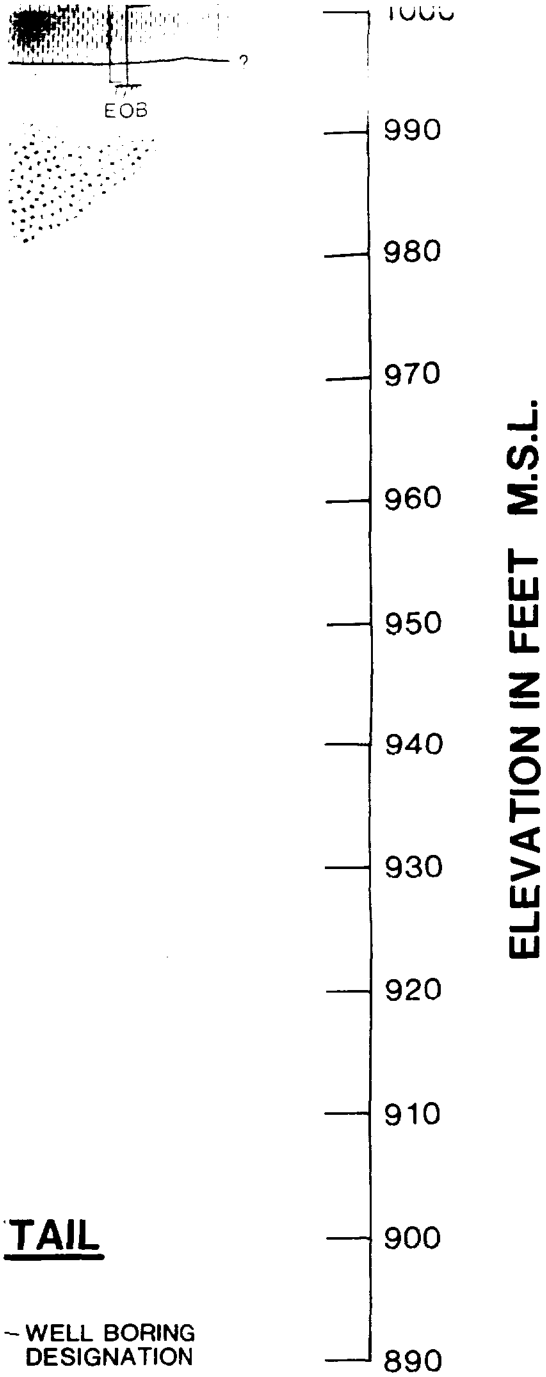
NON-CAD

GEOLOGIC CROSS SECTION C-C'

REMEDIAL INVESTIGATION / FEASIBILITY STUDY
HI-MILL MANUFACTURING COMPANY

FIGURE

8



TAIL

— WELL BORING DESIGNATION

REENED INTERVAL
HERE APPLICABLE)

D OF BORING

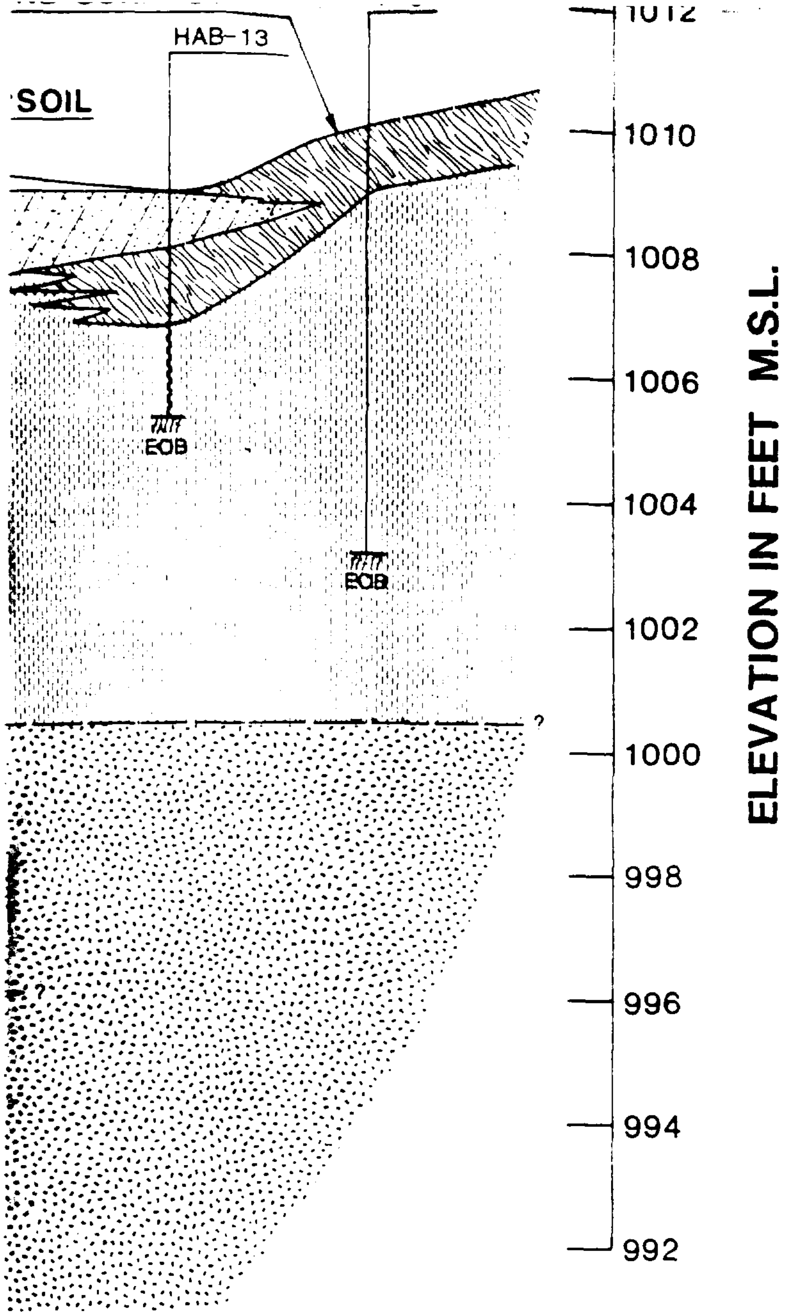
. NO PIEZOMETER INSTALLED.

NO: NON-CAD

GEOLOGIC CROSS SECTION D-D'

REMEDIAL INVESTIGATION / FEASIBILITY STUDY
HI-MILL MANUFACTURING COMPANY

FIGURE 9



BROWN/GREY VARIEGATED SILTY CLAY

BROWN SILT & SAND

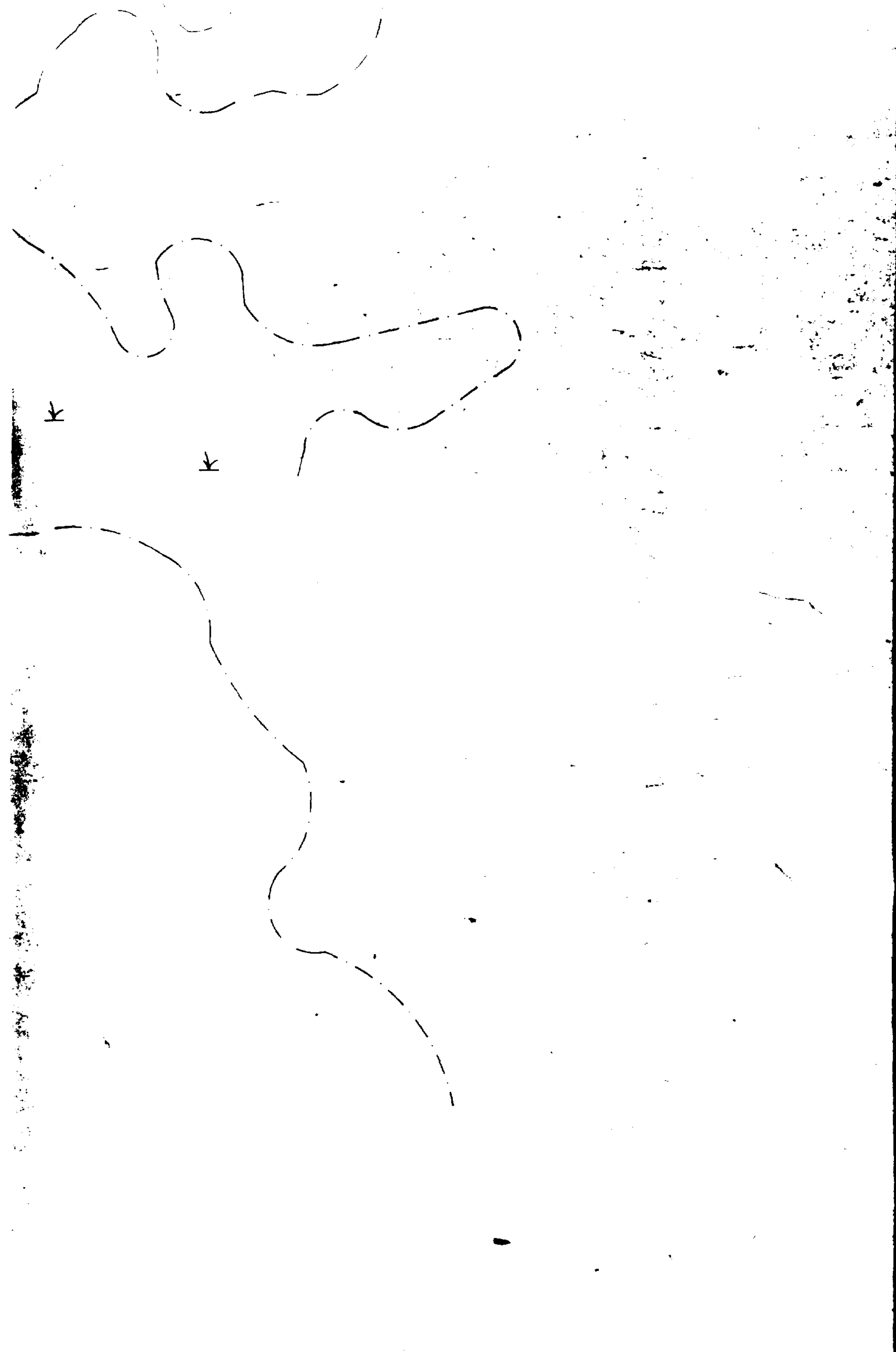
BROWN CLAYEY SILT

BROWN SAND

GREY / BLUE SILTY CLAY

BROWN SANDY SILT

FILE NO NON-CAD PLOT SIZE DATE DATE DATE	**GEOLOGIC CROSS SECTION E-E'** REMEDIAL INVESTIGATION / FEASIBILITY STUDY HI-MILL MANUFACTURING COMPANY	FIGURE **10**



BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

WELL LOCATION MAP REMEDIAL INVESTIGATION/FEASIBILITY STUDY HI-MILL MANUFACTURING HIGHLAND, MICHIGAN	FIGURE 11

BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

PHREATIC SURFACE OF THE "SHALLOW AQUIFER", MARCH 17, 1992

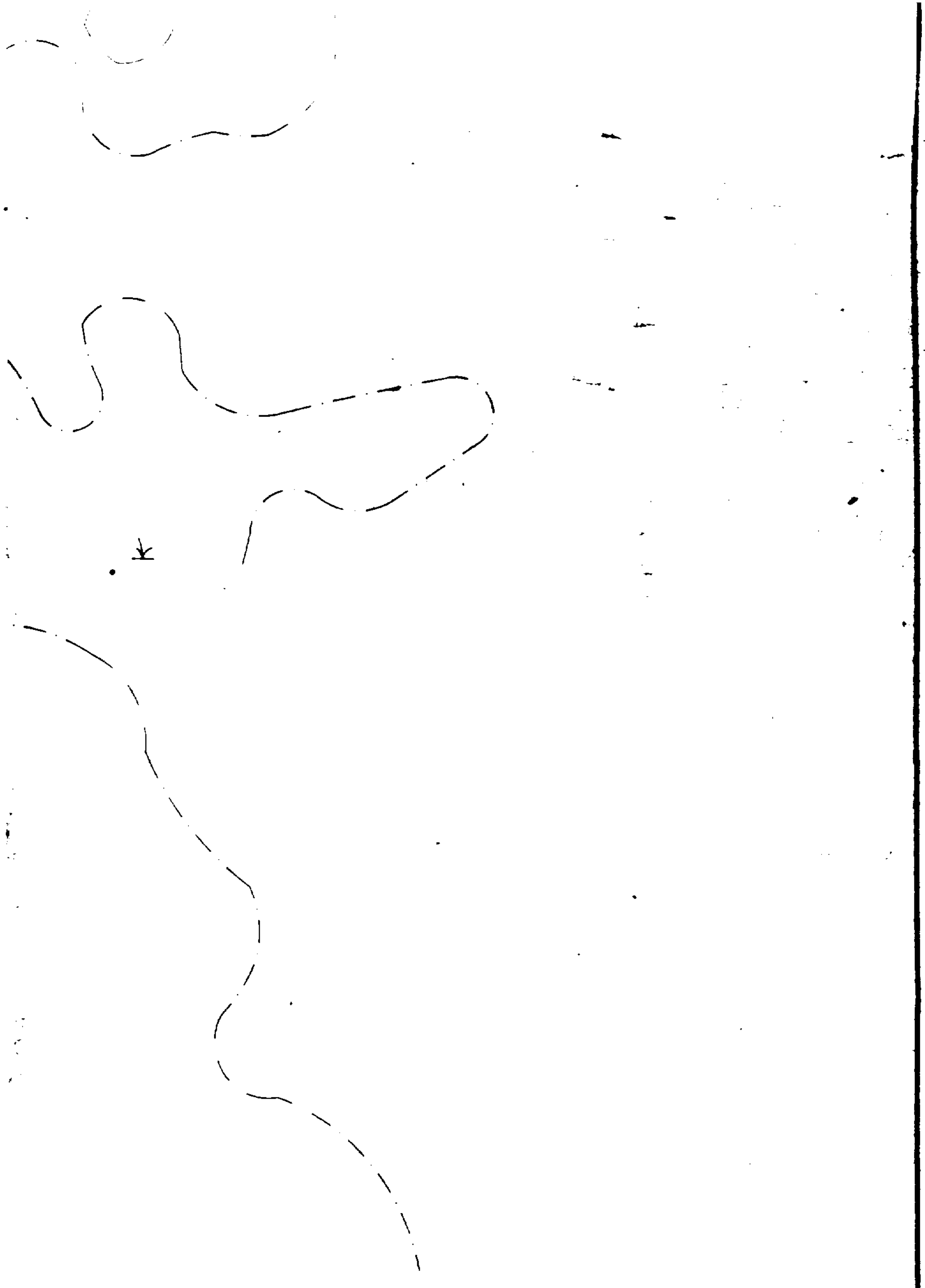
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING

HIGHLAND, MICHIGAN

FIGURE

12



BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

POTENTIOMETRIC SURFACE IN THE "INTERMEDIATE AQUIFER", MARCH 17, 1992

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING

HIGHLAND, MICHIGAN

FIGURE

13

BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

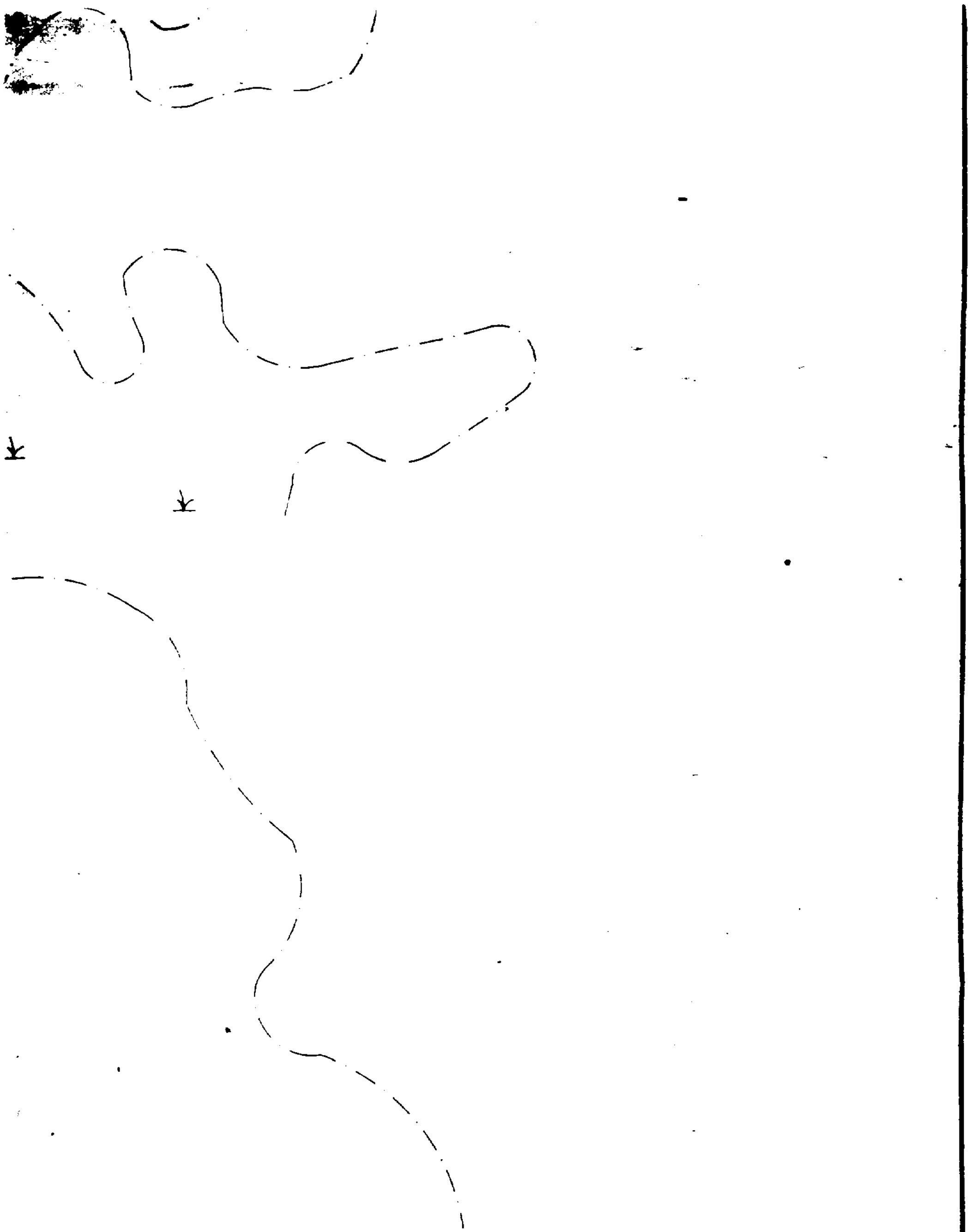
POTENTIOMETRIC SURFACE IN THE 'DEEP AQUIFER', MARCH 17, 1992

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING

HIGHLAND, MICHIGAN

FIGURE 14



BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

DISTRIBUTION OF INORGANIC COMPOUNDS IN SOIL

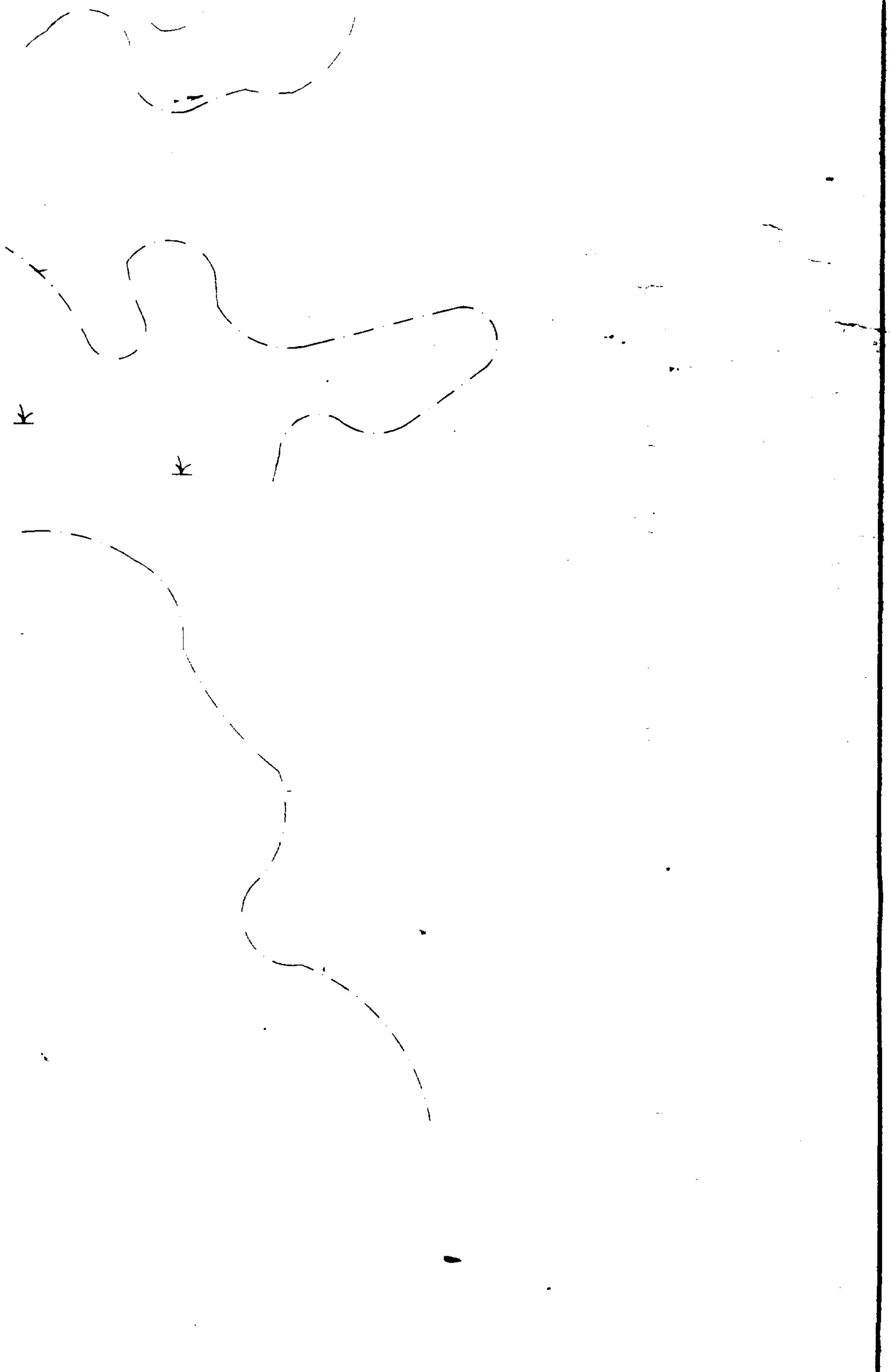
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HIMILL MANUFACTURING

HIGHLAND, MICHIGAN

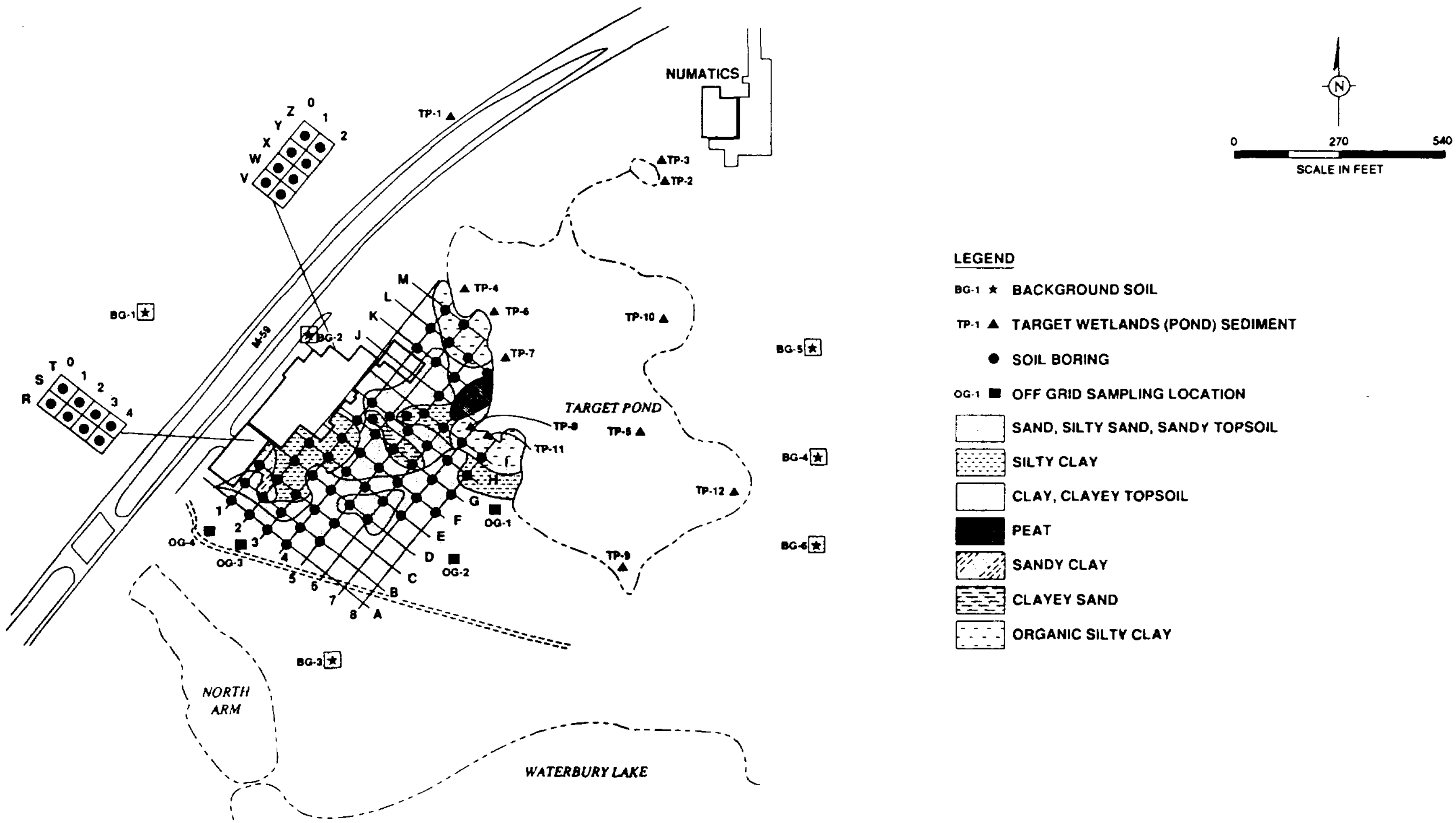
FIGURE

15



BASE MAP SOURCE: AYRES, LEWIS, NORRIS & MAY, INC., ANN ARBOR, MICHIGAN. DRAWING 88000-01, 2-17-92.

DISTRIBUTION OF INORGANIC COMPOUNDS IN GROUND-WATER REMEDIAL INVESTIGATION/FEASIBILITY STUDY HI-MILL MANUFACTURING HIGHLAND, MICHIGAN	FIGURE **16**



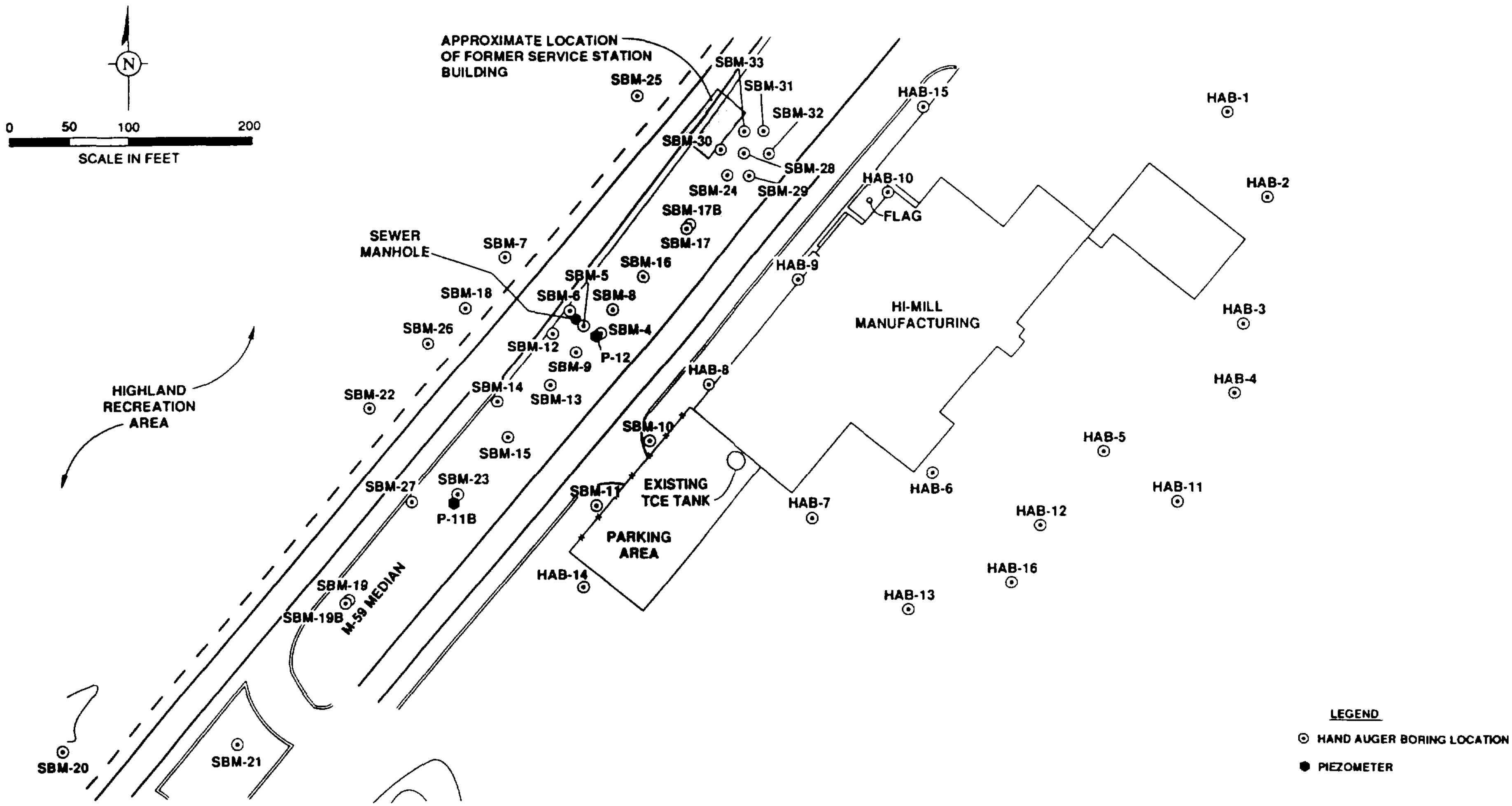
DRAFTER MS | APPROVED JJ | CHECKED RS | DRAWING 05 | FILE NO. 96 | PRJCT NO. MI319.02 | DWG DATE 02APR93

GERAGHTY & MILLER, INC.
Environmental Services

SOIL SAMPLES (0 TO 1 FT BELOW LAND SURFACE)
60 FT X 60 FT GRID SAMPLING LOCATION

HIMILL MANUFACTURING
HIGHLAND MICHIGAN

FIGURE
17



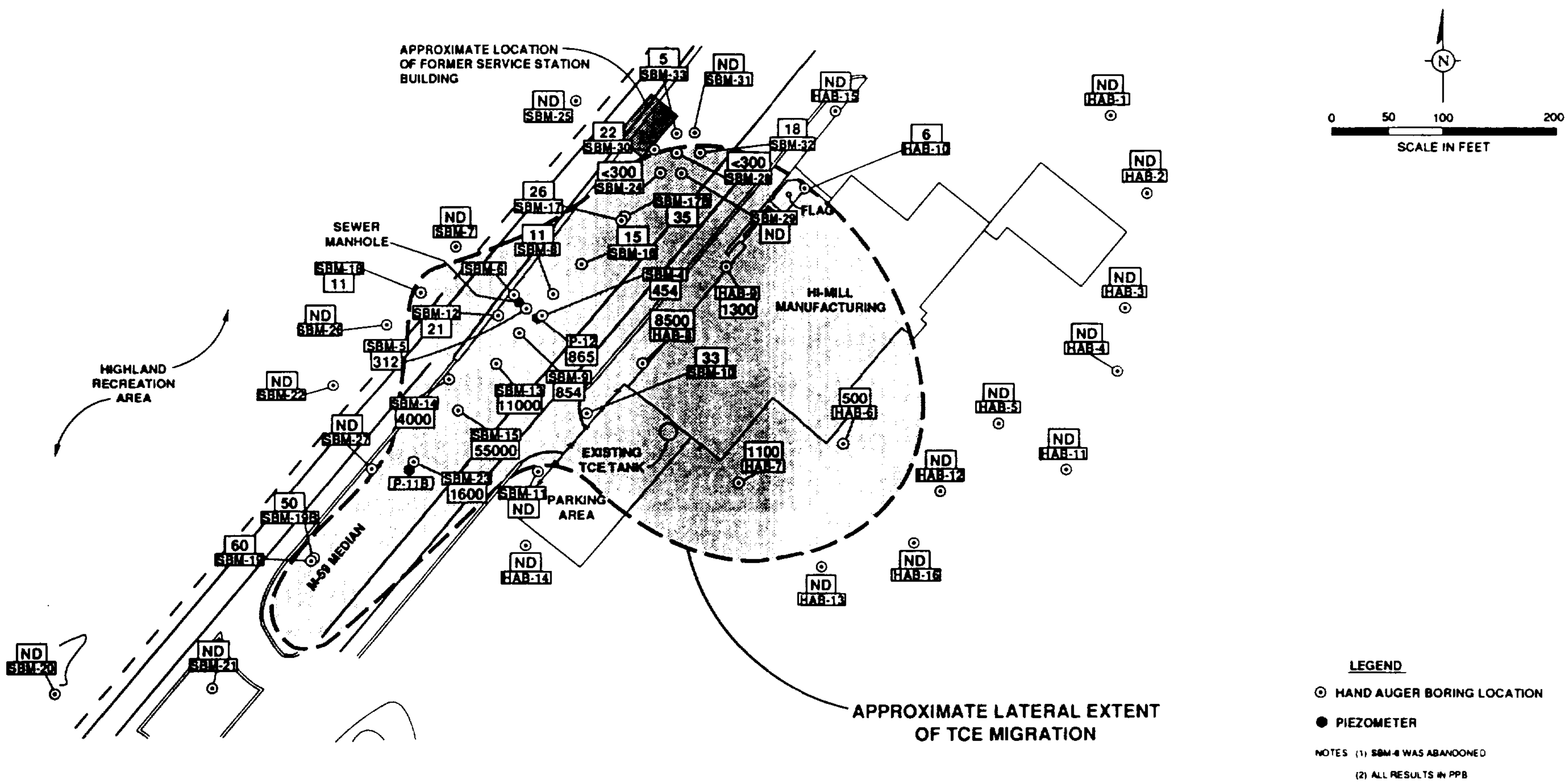
GERAGHTY & MILLER, INC.
Environmental Services

HAND AUGER BORING LOCATIONS

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE
18

DRAFTER: MS | APPROVED: JBJ | CHECKED: JBJ | DRAWING: 03 | FILE NO: 86 | PRJCT NO: MI0319.02 | DWG DATE: 02APR93



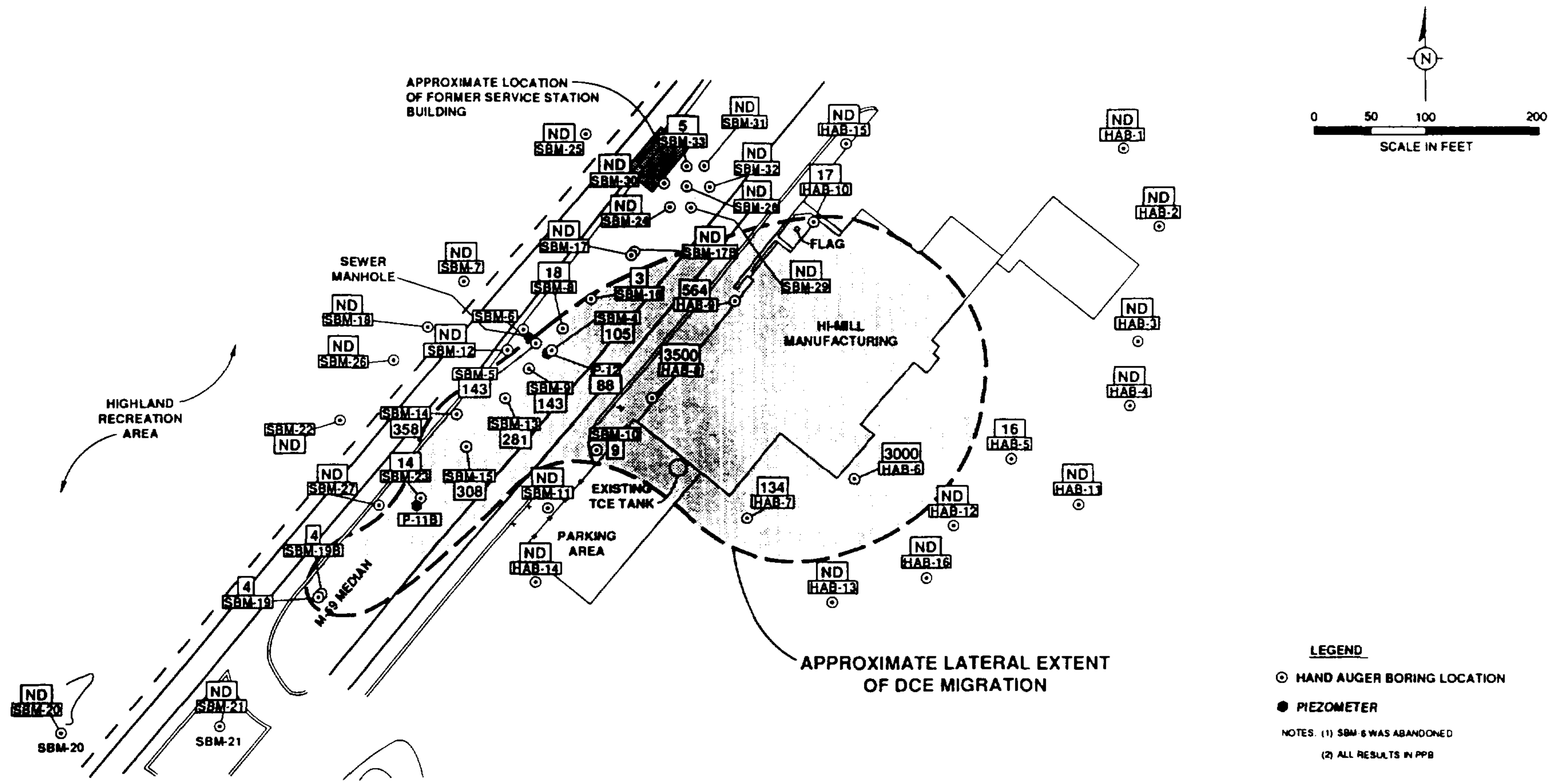
DRAFTER MS | APPROVED JBJ | CHECKED JBJ | DRAWING 07 | FILE NO 98 | PRJCT NO MI319.02 | DWG DATE 02APR93

GERAGHTY & MILLER, INC.
Environmental Services

MEDIAN INVESTIGATION
TCE DISTRIBUTION

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE
19



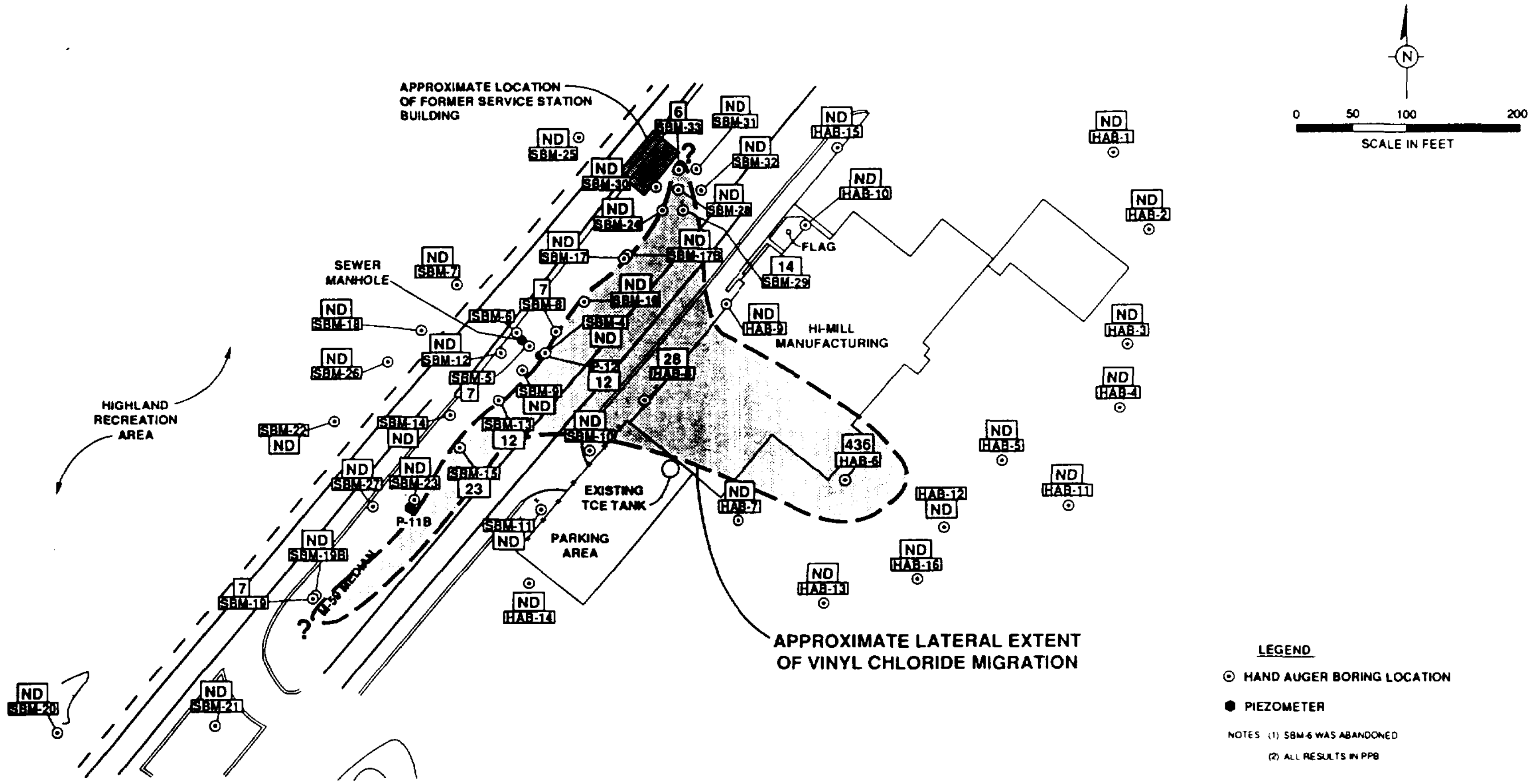
GERAGHTY & MILLER, INC.
Environmental Services

MEDIAN INVESTIGATION
DCE DISTRIBUTION

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 20

DWG DATE 02APR93 | PRJCT NO MI319.02 | FILE NO. 96 | DRAWING 06 | CHECKED RS | APPROVED JBJ | DRAFTER MS



LEGEND

⊙ HAND AUGER BORING LOCATION

● PIEZOMETER

NOTES (1) SBM-6 WAS ABANDONED

(2) ALL RESULTS IN PPB

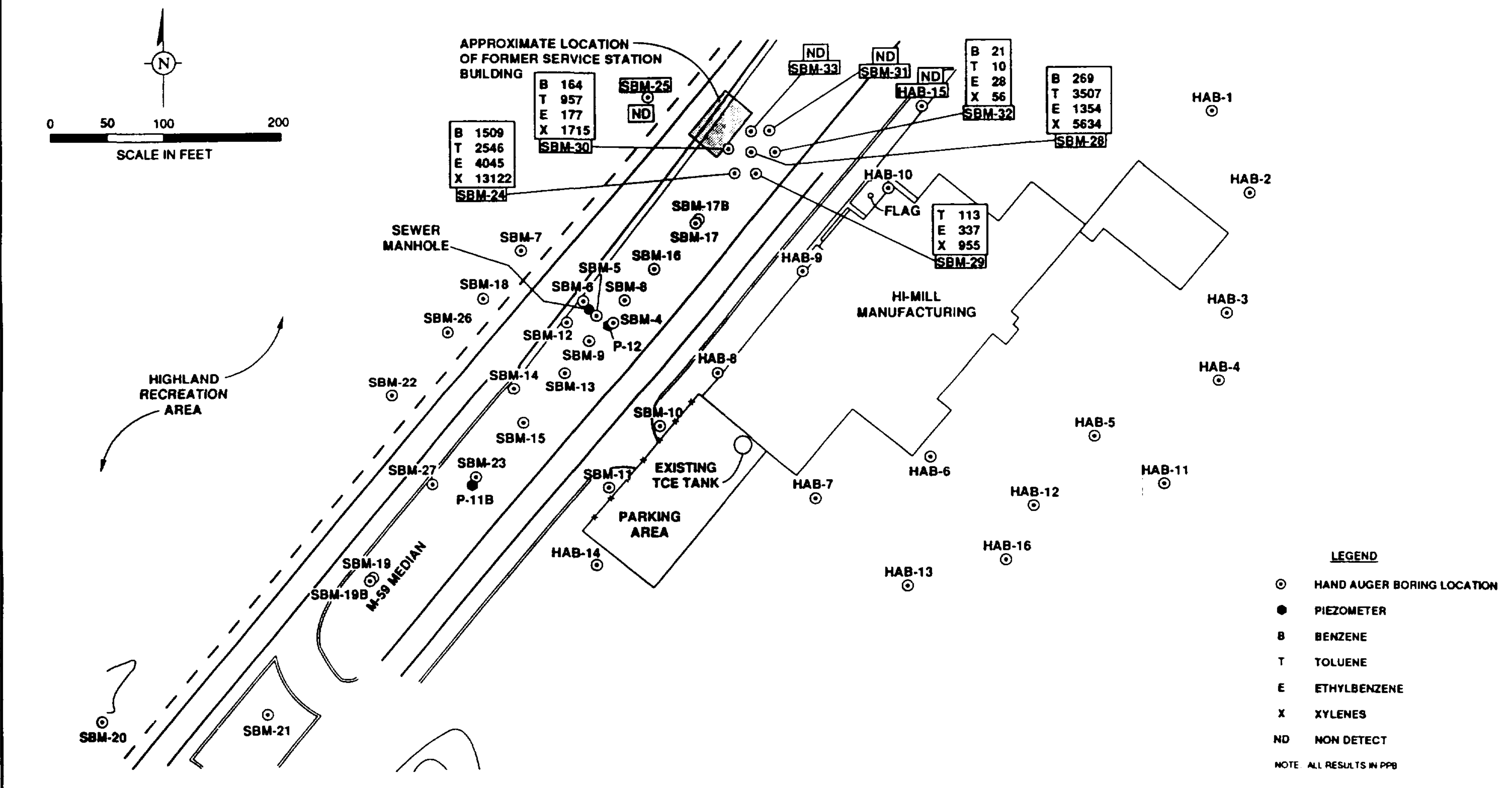
GERAGHTY & MILLER, INC. Environmental Services

MEDIAN INVESTIGATION
VINYL CHLORIDE DISTRIBUTION

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 21

DWG DATE 02APR93 | PRJCT NO MI319.02 | FILE NO 98 | DRAWING 09 | CHECKED RS | APPROVED JBJ | DRAFTER MS



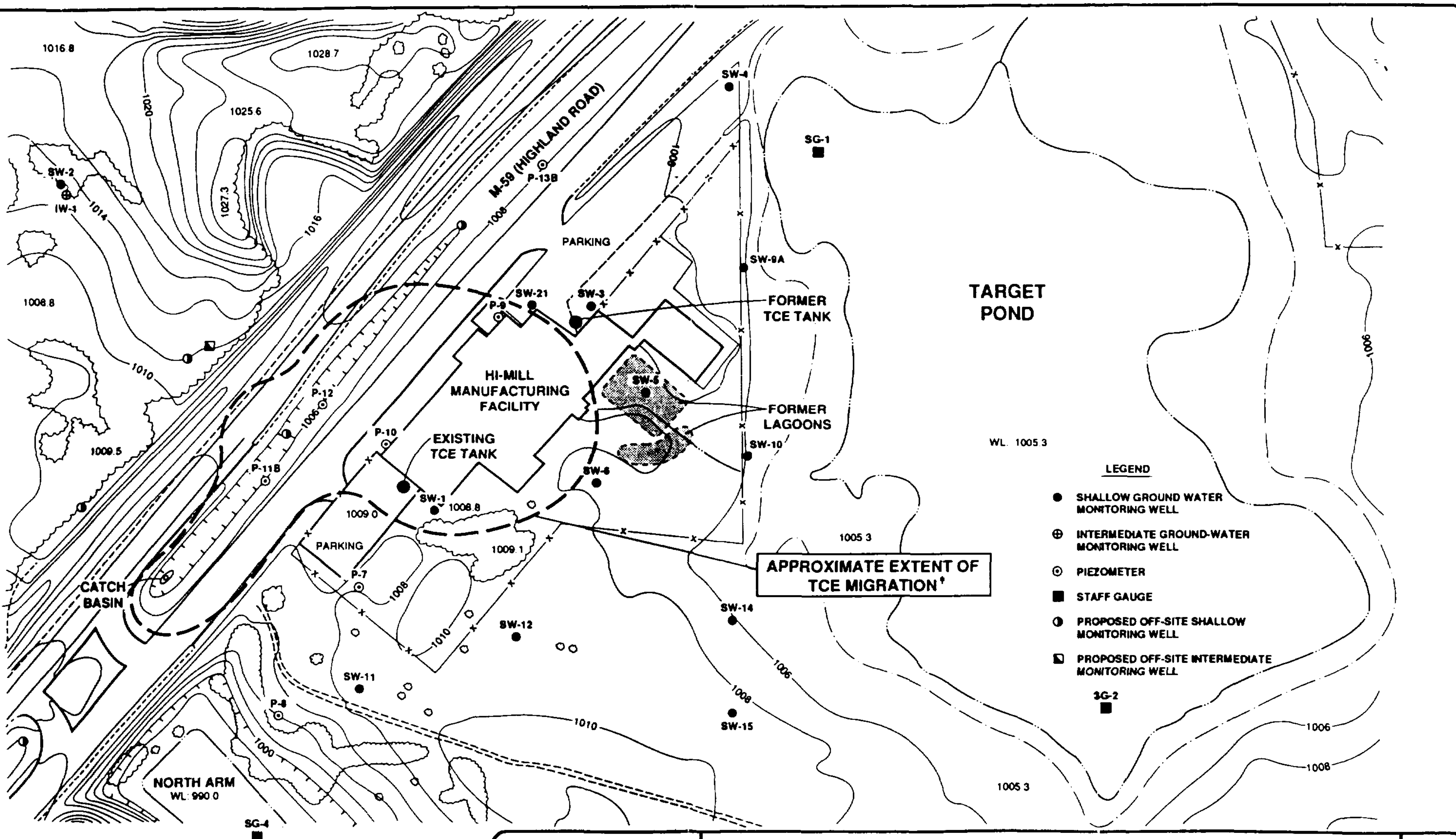
GERAGHTY & MILLER, INC.
Environmental Services

MEDIAN INVESTIGATION
BTEX DISTRIBUTION

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 22

DRAFTER: MS | APPROVED: JBJ | CHECKED: JBJ | DRAWING: 04 | FILE NO.: 98 | PRJCT NO.: MI319.02 | DWG DATE: 02APR93



† AS DETERMINED BY PORTABLE GAS CHROMATOGRAPH ANALYSIS IN GROUND WATER.

N

0 125 250

SCALE IN FEET

REFERENCE: ABRAMS AERIAL SURVEY, 1989.

NOTE: ALL ELEVATIONS REPORTED IN FT. MSL.

GERAGHTY & MILLER, INC.
Environmental Services

PROPOSED GROUND-WATER MONITORING NETWORK

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

FIGURE 23

DWG DATE: 06APR93 | PRJCT NO: MI019.02 | FILE NO: 0010 | DRAWING: 01 | CHECKED: JJ | APPROVED: JJ | DRAFTER: MS

SCALE IN FEET

DRAWING 88000-01, 2-?-92

400 N

EGEND:

SW-1 SHALLOW GROUND-WATER MONITORING WELL

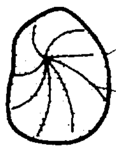
P-16 PIEZOMETER

WETLANDS

EW-1 EXISTING WELL

RW-1 SIMULATED VACUUM ENHANCED RECOVERY WELL LOCATION/NUMBER

1008 GROUND-WATER ELEVATION CONTOUR, FT. MSL (CONTOUR INTERVAL 1 FT.)



CONTAMINATION ZONE/LETTER

FLUID PARTICLE TRACKING

300 N

200 N

100 N

000 N

900 N

NOTE: ARBITRARY 100 ft. GRID ESTABLISHED BY GERAGHTY & MILLER USING SOUTHWEST CORNER OF PLANT AS 10,000 N/10,000 E AND ALONG WEST WALL AS PLANT NORTH BASELINE. GRID ESTABLISHED ON MARCH 10, 1993.

800 N

GROUND-WATER PUMPING RATES (GPM)

RW-1	.033
RW-2	.026
RW-3	.026
RW-4	.026
RW-5	.031
RW-6	.036
RW-7	.039
RW-8	.062

700 N

MEAN TRAVEL TIME = 20 YRS.
MEAN DISTANCE = 121 FT.
LONGEST DISTANCE = 300 FT.
LONGEST TRAVEL TIME = 68 YRS.

600 N

500 N

400 N

GROUND-WATER CAPTURE ZONE - ALTERNATIVE 3A

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 24

SCALE IN FEET

DRAWING 88003-01, 2-17-92.

10,400 N

10,300 N

10,200 N

10,100 N

10,000 N

9,900 N

9,800 N

9,700 N

9,600 N

9,500 N

9,400 N

LEGEND:

SW-1	SHALLOW GROUND-WATER MONITORING WELL
P-16	PIEZOMETER
	WETLANDS
EW-1	EXISTING WELL
10"	VACUUM DISTRIBUTION CONTOUR (CONTOUR INTERVAL 10" WATER)
0.05"	0.05" THRESHOLD VACUUM CONTOUR (INCHES WATER VACUUM)
	CONTAMINATION ZONE/LETTER

NOTE: ARBITRARY 100 ft. GRID ESTABLISHED BY GERAGHTY & MILLER USING SOUTHWEST CORNER OF PLANT AS 10,000 N/10,000 E AND ALONG WEST WALL AS PLANT NORTH BASELINE. GRID ESTABLISHED ON MARCH 10, 1993.

VAPOR FLOW RATES (CFM)

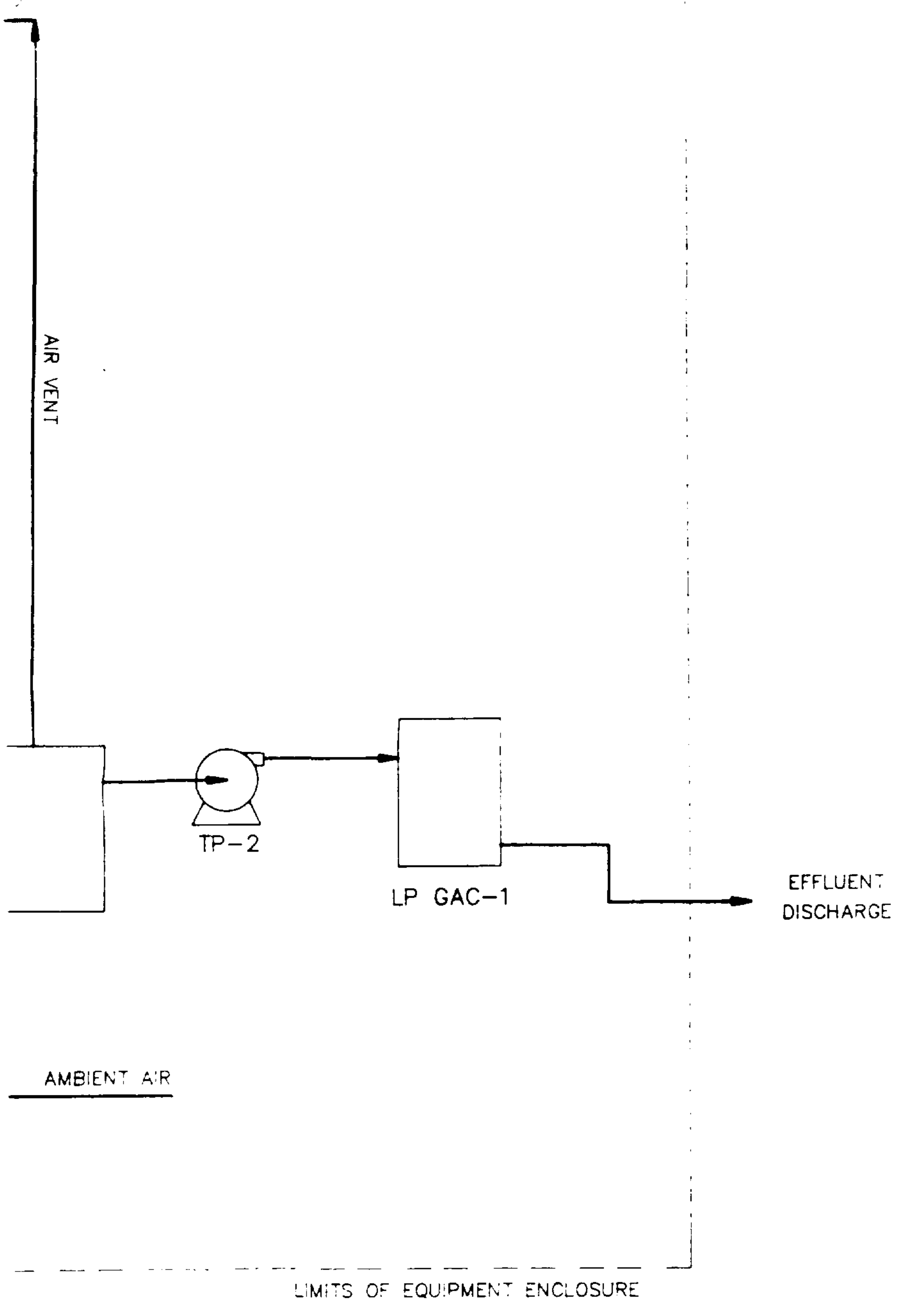
RW-1	33.0
RW-2	2.5
RW-3	2.5
RW-4	2.5
RW-5	2.5
RW-6	2.5
RW-7	2.5
RW-8	52.0

VAPOR FLOW ANALYSIS - ALTERNATIVES 3A AND 3B

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 25



PROCESS FLOW DIAGRAM - ALTERNATIVE 3A

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING

HIGHLAND, MICHIGAN

FIGURE

26

0 40 80 160

SCALE IN FEET

BASE MAP SOURCE: W/ EXCEPTION OF PLANT NORTH AND ARBITRARY 100 ft. GRID,
AYRES, LEWIS, NORRIS & MAY INC., ANN ARBOR, MICHIGAN.
DRAWING 88000-01, 2-17-92.

10,500 N

10,400 N

10,300 N

10,200 N

10,100 N

10,000 N

9,900 N

9,800 N

9,700 N

9,600 N

9,500 N

9,400 N

LEGEND:

SW-1 SHALLOW GROUND-WATER MONITORING WELL

P-16 PIEZOMETER

WETLANDS

EW-1 EXISTING WELL

RW-1 SIMULATED VACUUM ENHANCED RECOVERY WELL (RW-1 THRU RW-8)

RW-9 SIMULATED CONVENTIONAL GROUND-WATER RECOVERY WELL

1008 GROUND-WATER ELEVATION CONTOUR, FT. MSL (CONTOUR INTERVAL 1 FT.)

CONTAMINATION DELINEATION FOR TCE > 200 ppb IN M-59 MEDIAN

FLUID PARTICLE TRACKING

NOTE: ARBITRARY 100 ft. GRID ESTABLISHED BY GERAGHTY & MILLER USING SOUTHWEST CORNER OF PLANT AS 10,000 N/10,000 E AND ALONG WEST WALL AS PLANT NORTH BASELINE. GRID ESTABLISHED ON MARCH 10, 1993.

GROUND-WATER PUMPING RATE (GPM)

RW-1	.033
RW-2	.026
RW-3	.026
RW-4	.026
RW-5	.031
RW-6	.036
RW-7	.039
RW-8	.062
RW-9	0.13

GROUND-WATER CAPTURE ZONE - ALTERNATIVE 3B

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE 27

APPENDIX A

GROUND-WATER AND
VAPOR FLOW MODELING

CONTENTS

LIST OF FIGURES

LIST OF TABLES

COMPUTATIONS

1.0 INTRODUCTION

A groundwater flow model and a vapor flow model of the unsaturated subsurface underlying the Hi-Mill site was initiated to assess the effectiveness of vacuum enhanced recovery options and to assist in the conceptual design of a combined groundwater containment and vapor extraction remediation strategy for the treatment of volatile organic contaminants (VOCs). The purpose of this appendix is to describe the various components of the groundwater flow model and the vapor flow model and to discuss the results of the analysis.

The modeling analysis consisted of two tasks. The first task, the groundwater flow model, was used to analyze the placement and the pumping rates of wells intended to capture contaminated groundwater near the source areas and to determine how much dewatering of the shallow aquifer could be sustained without vacuum enhancement. The second component, the vapor flow model of the unsaturated subsurface, was used to determine the necessary flow rates and applied vacuum needed to extract VOCs from the soil.

2.0 CONCEPTUAL MODEL

2.1 Shallow Aquifer Groundwater Flow Model

A conceptual model is a descriptive representation of the physical flow system. The purpose of the conceptual model is to distill from the hydrogeologic data at the site the essential material parameters and physical properties in a form suitable for input into a mathematical code. Information from field measurements, such as soil borings and well log data, must be interpreted such that essential hydrogeologic parameters and conditions are represented on a scale and to a level of resolution commensurate with study objectives. Simplifying assumptions are formulated to interpolate measurements, collected at discrete locations, over the entire region of interest. Further assumptions accommodate spatially complex aquifer geometry (e.g., unit slope and thickness) and variable hydraulic parameters (e.g., hydraulic conductivity).

The shallow *aquifer* is the shallow discontinuous groundwater flow system referred to as the brown/grey variegated silty clay in the Final Remedial Investigation (G&M 1993). This unit is underlain by a tight, grey/blue silty clay. The grey/blue silty clay is several orders of magnitude less permeable than the brown/grey variegated silty clay. As such, the grey/blue clay can be represented by an impermeable boundary and serve as an aquifer base in the flow model. The brown/grey variegated silt unit has inter-bedded layers of silt and sand. For modeling purposes, this unit is assumed to be homogeneous in hydraulic conductivity (i.e., a continuum model of uniform hydraulic conductivity is chosen to be representative and essentially equivalent in hydraulic characteristics to a heterogenous, discontinuous porous medium).

Two distinct transmissivity zones are represented in the model. The first zone is indicated by the polygon encompassing the Hi-Mill building and environs in Figure A-1. This zone is has a base elevation of 1000 ft MSL. Areas beyond this zone have a reduced base elevation of 996 ft MSL to account for the decreasing elevation of the contact between the brown and the grey clay units and to account for the fact that the brown/gray variegated silty clay gradually diminishes and is replaced by a silty sand toward the median of M-59. Contours of the phreatic surface of the shallow aquifer (Figure 3.1 Final Remedial Investigation) indicate a change in gradient that likely coincides with the contrasting transmissivity zones in the model.

2.2 Unsaturated Zone Vapor Flow Model

The conceptual model for the unsaturated zone consists of an upper, variable leakage boundary with constant elevation and a lower impermeable boundary, also with constant elevation. The upper boundary is leaky in regions where the ground surface is open to vertical flow of air from the atmosphere. Non-leaky regions occur where the ground surface is closed to vertical flow of air (e.g., pavement, buildings, surface water bodies).

The primary simplifying assumption of the conceptual model is that the bottom boundary is maintained at a constant elevation. In reality, the bottom boundary will either be a water table with surface depressions near the groundwater extraction points (e.g., vacuum enhanced recovery wells), or, in the case where the shallow aquifer has been completely dewatered, the irregular surface of the contact between the brown and the grey clay. The net effect of these irregularities will be negligible in terms of the gross applied vacua and vapor extraction rates.

3.0 DESCRIPTION OF THE GROUNDWATER FLOW MODEL

3.1 Code Selection

In recent years, Geraghty & Miller has made use of a groundwater modeling technique called the analytic element method. The analytic element method was developed at the University of Minnesota Department of Civil and Mineral Engineering by Dr. Otto D. L. Strack. The method and its application to groundwater flow is described in the book Groundwater Mechanics (Strack, 1989).

The method simulates hydrogeologic features and phenomena with analytic functions rather than numerical approximation. Unlike numerical models, the aquifer is not subdivided. There is no loss of precision due to numerical approximation. Groundwater head, discharge potential, and stream function values can be computed at any point in a modeled aquifer without interpolation. The main advantages of conducting groundwater flow simulations with the analytic element method over a conventional numerical model are as follows:

- The model is infinite in areal extent (i.e., horizontal plane). Boundary conditions resulting from aquifer features (e.g., lakes, rivers, hydraulic conductivity and thickness inhomogeneities) are applied only at internal points; that is, the model does not require artificial boundary conditions to be applied at the outermost grid elements (e.g. finite difference grid boundaries);

- Groundwater velocities are computed by summing closed form expressions obtained by analytical differentiation of the discharge potential; and

- All functions representing aquifer features are given in closed form; therefore aquifer features included in a large regional model can be readily examined on a small, site-specific scale.

The computer code selected for the groundwater flow model of the Hi-Mill site is a single aquifer simulator called SLAEM. The acronym SLAEM signifies Single-Layer Analytic Element Model. This code, written and distributed by Dr. Strack, is an implementation of the analytic element method for single-layer, steady and time-dependent groundwater flow systems.

3.2 Technical Approach

In the analytic element method, analytic functions are used to represent various aquifer features. These functions may be overlain on an infinite flow domain using the principle of superposition. The functions vary in complexity, from the widely recognized Theim equation for a well, to complex expressions that are derived using conformal mapping techniques.

A theoretical basis of analytic element models, such as SLAEM, is the Dupuit-Forchheimer assumption. Strack (1989) states the Dupuit-Forchheimer assumption as *"the resistance to flow in the vertical direction is negligible"*. While there may be a vertical component of flow, it is not associated with a variation of hydraulic head. Hydraulic head, therefore, is constant along vertical slices in the modeled aquifer. This assumption is stated mathematically is terms of the specific discharge q_z and hydraulic head ϕ [L] as follows

$$\begin{aligned} q_z &\neq 0 \\ \frac{\partial \Phi}{\partial z} &= 0 \end{aligned} \tag{1}$$

Vertical flow is not neglected, therefore, it is possible to determine streamlines with a Dupuit-Forchheimer model (Strack 1989). The Dupuit assumption is particularly well-suited to the shallow aquifer at the Hi-Mill site because, in contrast, a deep aquifer is likely to have more resistance to vertical flow due to vertical anisotropy.

A fundamental concept of the method is that of the discharge potential. The discharge potential Φ [L^3/T] for unconfined flow, in terms of hydraulic head ϕ [L], hydraulic conductivity k [L/T], and aquifer base elevation b [L] is

$$\Phi = \frac{1}{2}k(\phi - b)^2 \tag{2}$$

The components of the discharge vector, oriented in the direction of groundwater flow in the horizontal x,y plane, are given in terms of the derivative of the potential as

$$\begin{aligned} Q_x &= -\frac{\partial \Phi}{\partial x} \\ Q_y &= -\frac{\partial \Phi}{\partial y} \end{aligned} \tag{3}$$

The components of the discharge vector are used in the SLAEM to compute groundwater velocities which, in turn, are used to track fluid particles so that a contaminant capture zone may be determined.

The analytic elements implemented in SLAEM and used in the model of the Hi-Mill site are given in terms of the symbol for the associated discharge potential as follows:

$$\begin{aligned} \Phi_{rn} &\rightarrow \textit{potential for known uniform infiltration} \\ \Phi_{wl} &\rightarrow \textit{potential for a well with known discharge} \\ \Lambda_{ar} &\rightarrow \textit{potential for an area element with unknown strength} \\ \Lambda_{db} &\rightarrow \textit{potential for transmissivity inhomogeneities} \end{aligned} \tag{4}$$

Some of the potentials consist of unknown parameters (e.g., the potential for transmissivity inhomogeneities), while others have known parameters (e.g., the potential for uniform infiltration). A system of equations is generated by specifying a condition at one *control* point, in the horizontal plane for each unknown parameter (i.e., one equation for each unknown). The combined potential for a given aquifer, for the condition imposed at a control point, is given in terms of the influence of all other elements. Once all of the unknown parameters are determined from solving a simultaneous system of linear equations, the potential, the hydraulic head, and velocity vector, are known for all points in the aquifer. This potential and its derivative are used at specified points to contour hydraulic head and to track fluid particles.

3.3 Hydrogeologic Framework and Model Configuration

The hydrogeologic framework embodies the salient features of the hydrogeologic system as described in the conceptual model. The SLAEM model consists of a single, unconfined aquifer. A summary of input parameters is listed in Table 1. Figure 1 shows the element layout of the SLAEM model.

Surface water features are represented in the groundwater model to simulate the interchange of surface water and groundwater. Target Pond (TP1, TP2, TP3, and TP4), Waterbury Lake (WL1, WL2, WL3, and NA1), and surface water bodies located at SG-5 and SG-6 are represented in SLAEM by area-elements. These elements require a fixed water elevation and a resistance parameter. The resistance parameter represents the resistance to vertical flow between the aquifer and the surface water body. This resistance is due to finer, less permeable lake sediments. The degree of resistance is a measure of the hydraulic connection of the surface water body to the aquifer. High resistance values signify limited hydraulic connection, while low resistance values signify good hydraulic connection. Flow is driven by the difference in water elevation above and below the lake sediments. Both Waterbury Lake and Target Pond are *gaining* lakes in the model simulations (i.e., receiving water from the aquifer). The resistance parameter is rarely measured in the field, rather it is largely a *free* parameter that is adjusted during the process of replicating observed water levels (*calibration*).

Two transmissivity zones are represented in the groundwater model. A reduced transmissivity zone encompasses the site (Figure 1). This zone has a hydraulic conductivity of 0.3 ft/day and a base elevation of 1000 ft. The region outside the reduced transmissivity zone has a hydraulic conductivity of 0.95 ft/day and a base elevation of 996 ft to reflect the decrease in base elevation at the median of M-59 (see 2.0 Conceptual Model). Estimates for these conductivities were obtained from the range of hydraulic conductivities predicted by analysis of baildown tests conducted at various on-site locations.

A uniform infiltration rate is applied over the site to simulate aquifer recharge. An infiltration rate of 1 to 4 inches per year was estimated using a water balance equation (refer to "Groundwater Recharge Estimation" in CALCULATION section). The infiltration estimate was obtained by incorporating mean monthly temperatures and precipitation values reported in Table 3.1 of the Final Remedial Investigation (1993). This information was used in a water balance equation summing precipitation and evaporation (runoff neglected). Approximately 4 inches per year was determined to be the upper bound infiltration rate.

3.4 Calibration

Groundwater model calibration is a fundamental objective of simulating steady-state groundwater flow conditions. Calibration is the process of adjusting parameter values to replicate measured water levels as accurately as possible. Parameters are adjusted within an acceptable range until a best fit between simulated and measured water levels is achieved. The key fitting parameters for matching observed water levels were as follows:

- the hydraulic conductivities of the two transmissivity zones; and
- the resistance to vertical flow of the area elements representing the surface water bodies.

The groundwater model is calibrated to water levels measured in the field on March 17, 1992 (Figure 3.1, Final Remedial Investigation). Simulated water level contours for the shallow aquifer generated from the calibrated model are shown in Figure A-2. A summary of calibration statistics is presented in Table 2 for 17 wells screened in the shallow aquifer. The sum of the errors between simulated and measured water levels is 2.7 (i.e, slight tendency to overpredict water levels). This number measures overall bias to predict water levels which are too high or too low. Ideally, this number would be zero, signifying no overall bias in the simulated water levels. The mean error between simulated and measured water levels is 0.16 ft (1.9 inches). The maximum errors occur at P-7 (i.e., model too low) and P-11B (i.e., model too high). The magnitude of error is acceptable for the resolution of the model and the objectives of the study.

4.0 DESCRIPTION OF THE VAPOR FLOW MODEL

4.1 Code Selection

Flow models are used in soil vapor extraction (SVE) system design to analyze gas pressures and flow fields induced by applying a vacuum to the unsaturated subsurface. A flow model is used to determine an optimal vapor extraction configuration and to adjust vapor extraction rates to achieve a required range of influence over a volume of contaminated soil. Geraghty & Miller has applied the analytic element method groundwater flow code SLAEM to simulate vapor flow in the unsaturated zone following the method described by Massmann (1989). SLAEM was chosen for the vapor flow analysis because of the following:

- subsurface flow is represented by analytic functions rather than numerical approximation;
- complex ground surface boundary conditions are readily incorporated in the model (e.g., paved and unpaved areas, buildings, wetlands, and lakes);
- fluid particle pathlines are rapidly and accurately analyzed (e.g., to determine the influence of vapor extraction wells) because flow velocities are directly

computed via analytic differentiation of the pressure field function; and

- Set-up time is minimal and computational requirements are modest in comparison to conventional finite-difference and finite-element flow models;

4.2 Technical Approach

Soil vapor extraction (SVE) is recognized as one of the most cost effective strategies for remediation of soils contaminated with volatile organic compounds. The governing equations of groundwater flow provide a good approximation to gas flow in the vadose zone, particularly when used to represent pressure gradients encountered in most SVE systems.

Massmann (1989) describes the application of groundwater flow models to SVE system design. The primary simplifying assumption is that Darcy's law is valid for gas flow. Using this approximation, so called *slip flow* must be neglected. Research indicates that neglecting slip flow is a good approximation for sands and gravels and a reasonably good approximation for silts and other fine-grained soils, such as those encountered in the shallow aquifer underlying the Hi-Mill site. Another key assumption is that gas flow can be modeled as an incompressible fluid. Research indicates this is valid for pressure ratios of 0.5 or greater.

A fundamental concept of the approach is that of the discharge potential. The vapor flow model assumes that flow in the unsaturated zone is analogous to groundwater flow in a confined aquifer. The discharge potential Φ [L^3/T] for confined vapor flow is expressed in terms of pressure head, gas conductivity k_g [L/T], subsurface thickness H [L] and water table elevation b [L] as

$$\Phi = k_g H(\phi - b) - \frac{1}{2}kH^2 \tag{5}$$

A SLAEM vapor flow model incorporates a discharge potential that embodies all sources and sinks in the unsaturated zone (e.g., vertical flow of uncontaminated air from the atmosphere and vapor extraction points). The components of the discharge vector, oriented in the direction of vapor flow in the subsurface (i.e., horizontal x,y plane), are given in terms of the derivative of the potential as

$$
\begin{aligned}
Q_x &= -\frac{\partial \Phi}{\partial x} \\
Q_y &= -\frac{\partial \Phi}{\partial y}
\end{aligned}
\qquad (6)
$$

The components of the discharge vector are used in the SLAEM to compute velocities which, in turn, are used to track vapor particles to determine the effective influence of vapor extraction wells.

A vapor flow model of the unsaturated subsurface underlying the Hi-Mill site was initiated to assess the effectiveness of soil vapor recovery and to assist in the conceptual design of the vacuum enhanced recovery system. The vapor flow model was used to define vapor extraction rates, to determine the areal influence of each recovery well in various configurations, and to delineate vapor recovery zones.

4.3 Gas Conductivity Estimate

Gas conductivity is an important input parameter in vapor flow simulations in unsaturated soil. Gas conductivity for the Hi-Mill site was estimated from the horizontal, hydraulic conductivities obtained from baildown tests conducted in the shallow aquifer. The intrinsic permeability is calculated for the soil in the shallow aquifer because this parameter is dependent on soil properties and independent of the properties of the fluid flowing through it. Once an estimate of the intrinsic permeability is known, the gas conductivity is estimated. The intrinsic permeability κ is given by the following equation:

$$\kappa = \frac{k\mu}{\rho g} \qquad (7)$$

where

- k horizontal hydraulic conductivity [L/T];
- μ viscosity of groundwater at 15.5 degrees C [M/(LT)];
- ρ density of groundwater at 15.5 degrees C [M/L^3]; and
- g gravitational constant [L/T^2].

The arithmetic mean of the horizontal hydraulic conductivities for baildown tests conducted at wells screened within or above the brown clay (e.g., SW-4, SW-9A, and SW-15 from Table 3.8 of the Remedial Investigation), i.e., 0.0008 cm/sec, was used to estimate the intrinsic permeability. The groundwater density and viscosity (at 15.5 degrees C) were assumed to be 1.0 g/cm^3 and 0.01124 g/(cm sec), respectively (pg. 529, Freeze and Cherry 1979). Equation

(1) gives an estimate of intrinsic permeability of 9.0E-9 cm^2 for the site. This is characteristic of the low to mid-range for a silty sand (pg. 29, Freeze and Cherry 1979).

Using the estimated intrinsic permeability, a gas conductivity k_g is estimated by rearranging equation (7) as follows:

$$k_g = \frac{\kappa \rho g}{\mu} \tag{8}$$

A gas density and viscosity were assumed to be 0.0013 g/cm^3 and 0.00018 g/(cm sec), respectively (pg. 140, Massmann 1989). The gas conductivity, computed from equation (8), is approximately 6.0E-5 cm/s or 0.17 ft/day.

4.4 Subsurface Representation

The vapor flow model consists of a single confined layer that is homogeneous in conductivity and in thickness. Table 3 provides a summary of the input parameters specified for the SLAEM vapor flow simulations.

Two subsurface geometries were considered. The first assumed an unsaturated thickness that reflected a complete dewatering of the shallow aquifer. This thickness is approximately 10 feet (e.g., mean distance from ground surface to the contact between the brown/grey variegated silty clay and grey/blue silty clay in the vicinity of the Hi-Mill building as shown in section E-E' of the Remedial Investigation). The second assumed an unsaturated thickness that reflected a modest amount of dewatering of the shallow aquifer on the order of a few feet so that the unsaturated thickness was about 5 ft.

Soil open to the atmosphere was represented by area source elements. These areas were located primarily to the rear of the Hi-Mill building, along the front of the building, and in the median of M-59. Area sources are fixed pressure-head elements with a resistive membrane (e.g., top soil and vegetative cover) that simulate vertical leakage of uncontaminated air from the atmosphere. The resistance to vertical flow from the atmosphere is defined as follows:

$$c = \frac{H}{k_v} \tag{9}$$

where

c	resistance parameter [T]
H	thickness resistive layer [L]; and
k_v	vertical gas conductivity [L/T];

The resistance used for all area sources across the site was approximately 286 days. This resistance was computed by assuming a 1 ft resistive layer and a vertical gas conductivity twenty times less conductive than the horizontal gas conductivity estimated for the site. Flow through the topsoil membrane is controlled by the difference between atmospheric pressure and the gas pressure in the subsurface. Exchange of air from the atmosphere is driven by the vacuum applied at the vapor extraction points.

5.0 GROUNDWATER FLOW MODEL RESULTS

5.1 Scenario I Contaminant Capture Zone Analysis

Scenario I consists of capturing all on-site contamination emanating from contamination delineation zones A, B, C, and D (Figure 1). In this scenario, no off-site contamination is considered. Figure A-3 shows a plot consisting of contours of simulated water levels and of fluid particle paths originating at the edges of the contamination delineation zones. Eight vacuum enhanced recovery wells are placed around the Hi-Mill building to capture contamination and to limit off-site contaminant migration. These wells are pumping an average of 0.03 gpm. At these pumping rates, all fluid particles emanating from the contamination delineation zones are captured. The simulated wells all use~~ing~~ the maximum available drawdown in the shallow aquifer. In addition the simulated wells are 100 percent efficient. It is unlikely that these pumping rates could be consistently sustained by conventional extraction wells due to the limited available drawdown and well inefficiency due to the disturbance of soil around the well bore. However, Blake, et. al (1990) have found that vacuum enhanced recovery wells in similar low permeability aquifers can support pumping rates that are 3 to 5 times higher than conventional extraction wells.

5.2 Scenario II Contaminant Capture Zone Analysis

Scenario II consists of capturing all on-site contamination emanating from contamination delineation zones A, B, C, and D (Figure 1) and capturing contamination between P-11B and P-12 in the median of M-59. In this scenario, both on-site and off-site contamination is considered. Figure A-4 shows a plot consisting of contours of simulated water levels and of fluid particle paths originating at the edges of the contamination delineation zone in the median. The contamination delineation zone in the median is intended to encompass TCE contamination in excess of 200 ppb (source: Figure 4.11, Final Remedial Investigation). A single well is placed in the median adjacent to SBM-15 where the highest concentration of TCE was detected. This well is intended to be a conventional groundwater extraction well with a simulated pumping rate of 0.13 gpm.

6.0 VAPOR FLOW MODEL RESULTS

6.1 Applied Vacua and Flow Rates

Massman (1989) indicates that neglecting slip flow is appropriate for pressure ratios of 0.5 or greater, that is,

$$\frac{P_v}{P_0} \geq 0.5 \tag{10}$$

where

P_v steady state pressure after vacuum is applied; and
P_v ambient atmospheric pressure.

The mean pressure ratio for the vapor flow for the eight recovery wells is 0.72. The total extraction rate is estimated from the vapor flow model to be about 100 cubic feet per minute (cfm).

The applied vacuum range in the vapor flow model is about 200 to 300 inches of water at the extraction points. Wells requiring a large range of influence and wells adjacent to large areas open to the atmosphere generally need a much higher flow rate. Individual flow rates range from 2.5 cfm for the wells along the front of the Hi-Mill building to 52 cfm for the well behind the building.

6.2 Sensitivity Analysis

Two subsurface geometries were considered in the vapor flow modeling task since mass removal via vapor extraction depends on the amount of dewatering that can be sustained . One flow geometry assumed an unsaturated thickness of 10 ft, reflecting a complete dewatering of the shallow aquifer. The other flow geometry assumed an unsaturated thickness of 5 ft, reflecting a modest amount of dewatering of the shallow aquifer. The vapor flow model was not sensitive to a doubling of the thickness of the unsaturated zone. This would seem to imply that the model is insensitive to changes in transmissivity, however, the gas conductivity used for the model was based on an intrinsic permeability determined from an estimated hydraulic conductivity at the site. Gas conductivity for silty materials can range over orders of magnitude. Therefore, if the model had incorporated a site specific gas conductivity, derived from a pneumatic pumping test for example, doubling the transmissivity due to changes in unsaturated thickness would not significantly effect the vacuum distribution and the associated areal influence of the vapor extraction points.

The areal influence of the vapor extraction points is sensitive to the resistances chosen for the soil / air interface. In the absence of a pilot test at the site, estimation of this parameter is somewhat arbitrary. A highly resistive ground surface restricts the vertical flow of air from the atmosphere and greatly enhances the areal influence of the vapor extraction points.

6.3 Analysis of Areal Influence

A vacuum of 0.05 inches of water was assumed to be the effective influence of the vapor extraction component of the vacuum enhanced recovery wells. Vacua below this threshold are difficult to verify with field measurements. Figure A-5 shows contours of vacuum induced by the eight vacuum enhanced recovery wells under both groundwater extraction scenarios. The contamination delineations for groundwater recovery, that is zone A, zone B, zone C and zone D, were also used as the guideline for VOC vapor recovery. The highest levels of soil contamination, including the spill location, are located in a zone with greater than 10 inches of water vacuum. Furthermore, the 0.05 inches of water vacuum threshold covers a majority of the contaminated soil (e.g., Zones A, B, and D fall within 100 feet of the 0.05 threshold). The range of vacuum distribution in the periphery of zone C could be enhanced by implementing measures to block the vertical migration of air at the soil / air interface.

7.0 CONCLUSIONS

The groundwater model gives an estimate of the number of wells and the magnitude of recovery rates needed to control on-site and off-site groundwater contamination. The groundwater model shows that the prevailing hydrogeologic conditions at the Hi-Mill site represent the practical limits of a conventional recovery well system for capturing contaminated groundwater. Such recovery wells systems are constrained by the available drawdown. As such, in a shallow, low permeability aquifer, a conventional groundwater recovery systems are likely to be unable to sustain a sufficient amount of discharge to entrain contaminated groundwater. Assuming 100 percent well efficiency, and, assuming that the saturated thickness remains at the simulated levels, model results indicate that a conventional extraction well system might suffice to entrain contaminated groundwater at the Hi-Mill site. However, given the practical realities of well efficiency, and given the transient, seasonal fluctuations of the water table, a conventional extraction well system is not a viable option. Vacuum enhanced recovery technology provides the additional available drawdown to control off-site migration of contamination.

The vapor flow model demonstrates the magnitude of applied vacua and flow rates necessary to extract soil vapors at the Hi-Mill site. The range of applied vacua (e.g., 200-300 inches of water) and the flow rates are well within the performance specifications for vacuum enhanced recovery technology. A significant vacuum distribution, in excess of 10 inches of water, is readily applied over the most highly contaminated zones at the site. Furthermore, all contaminated zones have been shown in the vapor flow simulation to have a threshold vacuum of 0.05 inches of water or greater. The vapor flow simulation gives an order of magnitude estimate of the actual conditions. The vapor flow model can be readily calibrated to subsequent pilot test data to yield a more accurate prediction of actual field performance.

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TABLES

TABLE 1. SUMMARY OF INPUT PARAMETERS FOR GROUNDWATER FLOW SIMULATIONS

hydraulic conductivity	0.30[1] / 0.95[2] ft/ day	
base elevation	1000[1] / 996[2] ft MSL	
infiltration rate	1.2 inches per year [3]	
Surface Water:	<u>Elevations</u>	<u>Resistances</u>
WL1 (Waterbury Lake)	999.42 ft	100 days
WL2 (Waterbury Lake)	999.42 ft	400 days
WL3 (Waterbury Lake)	999.42 ft	400 days
NA1 (North Arm)	999.47 ft	600 days
TP1 (Target Pond)	1005.54 ft	10 days
TP2 (Target Pond)	1005.48 ft	10 days
TP3 (Target Pond)	1005.48 ft	10 days
TP4 (Target Pond)	1005.54 ft	20 days
SG5 (Staff Gauge)	998.69 ft	200 days
SG6 (Staff Gauge)	1005.61 ft	10 days

(1) Reduced transmissivity region in the vicinity of the Hi-Mill plant (see Figure 1)

(2) Off-site regions

(3) Refer to "Groundwater Recharge Estimation" Calculation Sheets for upper bound recharge estimate

TABLE 2. SHALLOW AQUIFER GROUNDWATER MODEL CALIBRATION SUMMARY

Well I.D.	Model X Coordinates	Model Y Coordinates	Simulated Head (ft MSL)	Measured Head (ft MSL)	Error
SW-2	9447.7	10044.9	996.42	996.42	0.00
SW-3	10079.0	10339.7	1007.66	1008.10	-0.44
SW-4	10051.2	10672.4	1005.72	1006.34	-0.62
SW-5	10221.6	10294.5	1007.91	1008.06	-0.15
SW-9A	10223.2	10500.0	1006.57	1005.01	1.56
SW-10	10375.0	10314.0	1007.08	1005.65	1.43
SW-15	10632.5	10075.9	1007.44	1007.02	0.42
P-3	11281.4	10047.3	1004.42	1004.30	0.12
P-6	10553.4	9623.3	1005.19	1006.81	-1.62
P-6RD	10515.8	9540.2	1002.40	1002.11	0.29
P-7	10090.9	9840.5	1006.97	1008.69	-1.72
P-8	10115.6	9641.5	1003.40	1003.98	-0.58
P-9	10005.2	10241.5	1007.59	1008.00	-0.41
P-10	9992.6	10016.9	1007.08	1007.30	-0.22
P-11B	9888.6	9814.5	1004.34	1002.51	1.83
P-12	9893.8	9998.8	1005.09	1003.55	1.54
P-15	9716.5	9587.8	1001.44	1000.13	1.31

sum of errors =	2.72
mean error =	0.16
max. under =	-1.72
max. over =	1.83

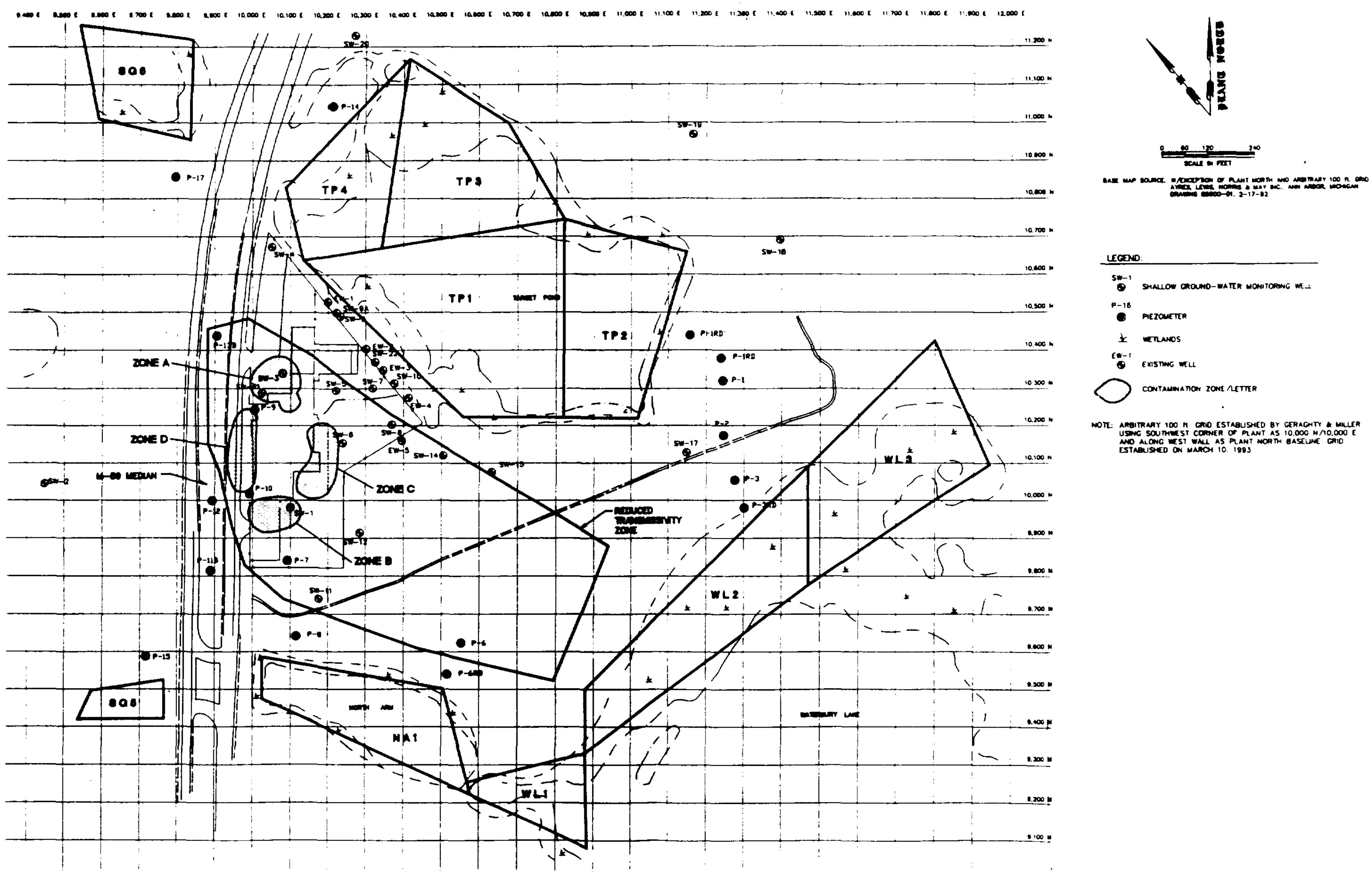
i:\mi31901\report\table2.wb1

TABLE 3. SUMMARY OF INPUT PARAMETERS FOR VAPOR FLOW SIMULATIONS

gas conductivity	0.07 feet of gas per day
unsaturated thickness	10 ft [1] / 5 ft[2]
area source resistance	286 days
atmospheric pressure	27,477 ft of gas
base elevation	0 ft

[1] unsaturated thickness assuming a complete dewatering of the shallow aquifer
[2] unsaturated thickness assuming a modest amount of dewatering of the shallow aquifer

FIGURES



NOTE: ARBITRARY 100 ft. GRID ESTABLISHED BY GERAGHTY & MILLER USING SOUTHWEST CORNER OF PLANT AS 10,000 N/10,000 E AND ALONG WEST WALL AS PLANT NORTH BASELINE GRID ESTABLISHED ON MARCH 10, 1993

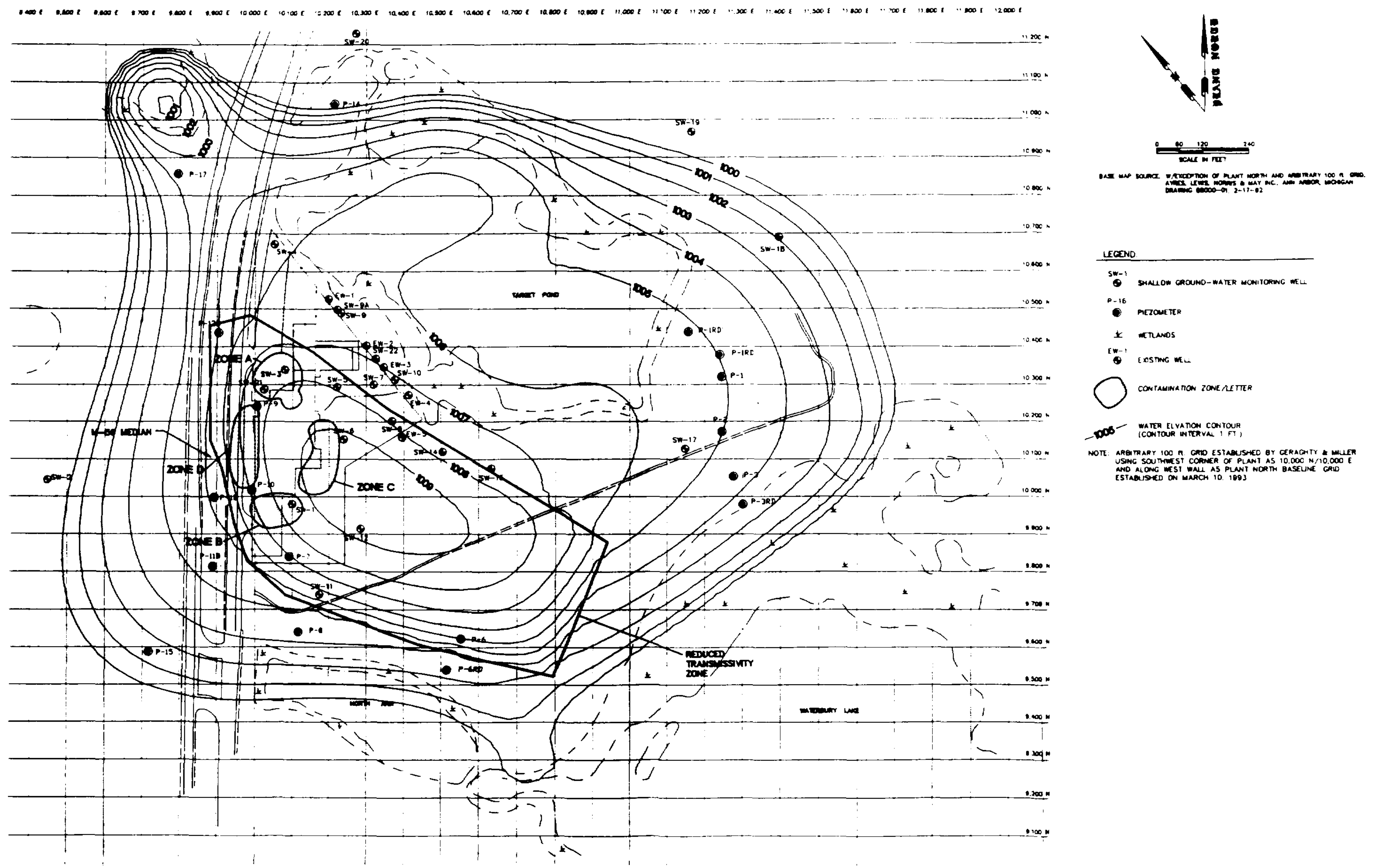
GERAGHTY & MILLER, INC.
Environmental Services

GROUND-WATER MODEL ELEMENT LAYOUT

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE A-1



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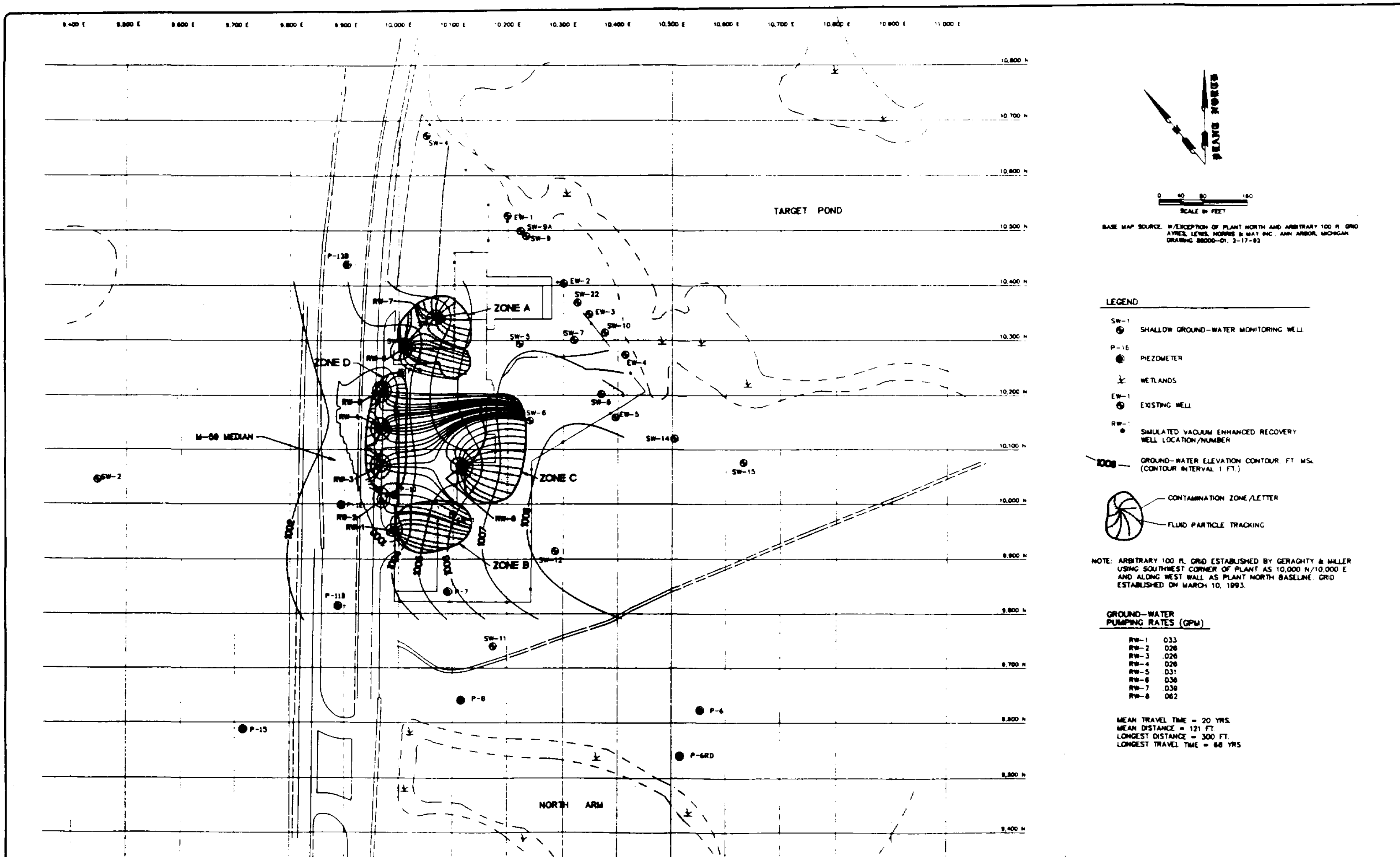
REV NO.	DATE	DESCRIPTION	BY	APPR

CALIBRATED GROUND-WATER MODEL

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE A-2



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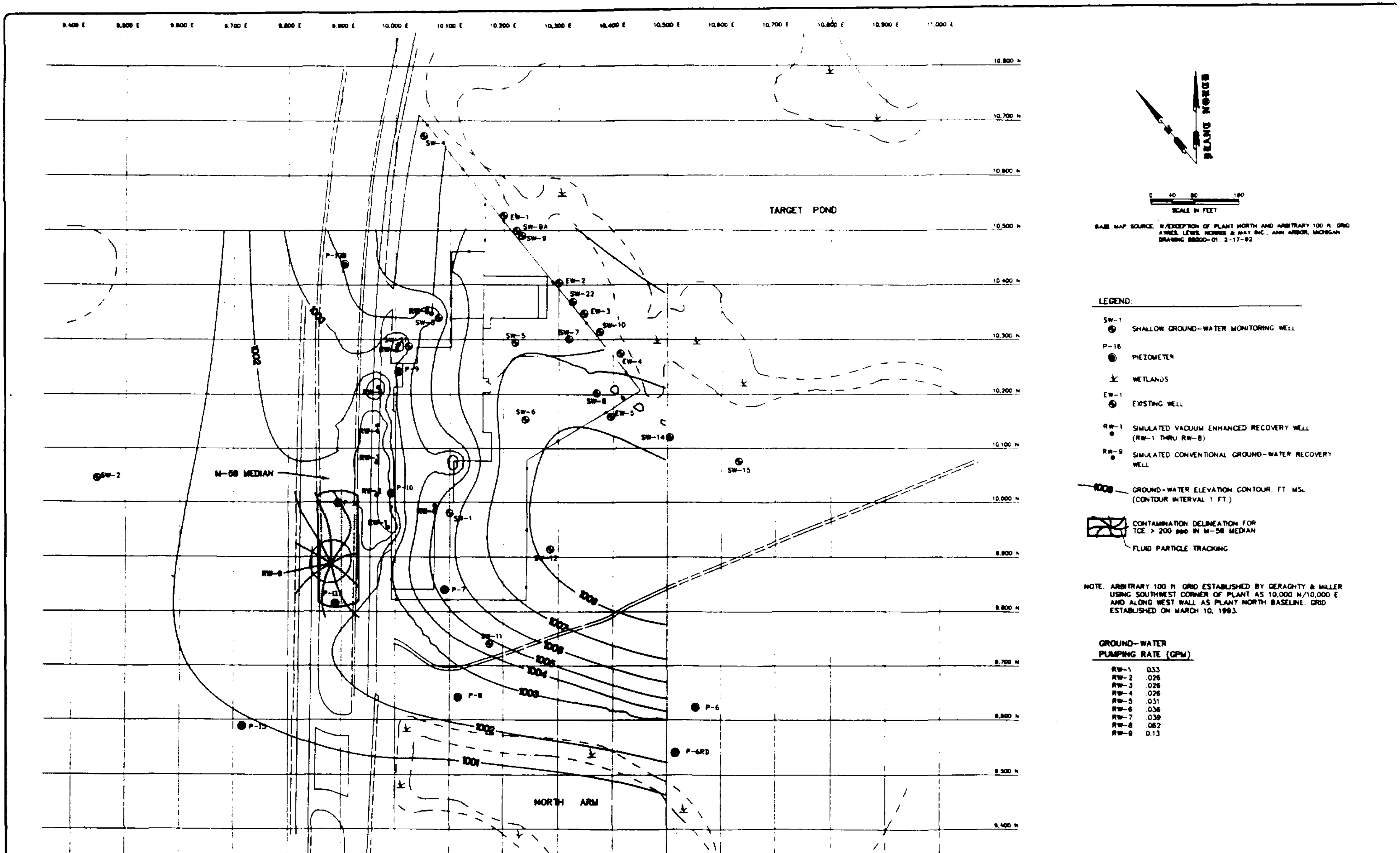
REV. NO.	DATE	DESCRIPTION	BY	APPR

GROUND-WATER CAPTURE ZONE ANALYSIS

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE A-3



GERAGHTY & MILLER, INC.
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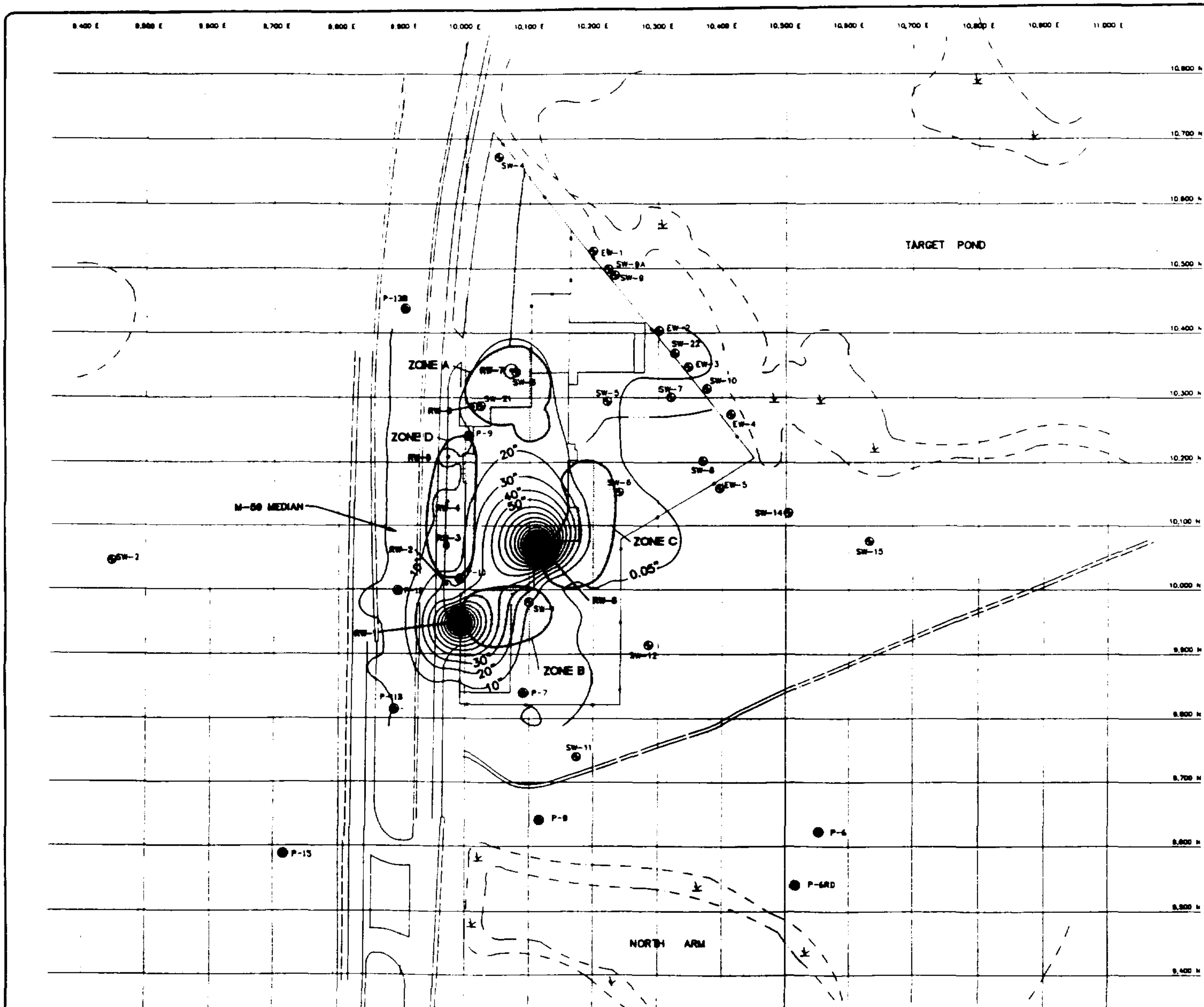
REV. NO.	DATE	DESCRIPTION	BY	APPR

MEDIAN GROUND-WATER CAPTURE ZONE ANALYSIS

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE A-4



SCALE IN FEET (0, 40, 80, 160)

BASE MAP SOURCE: W/EXCEPTION OF PLANT NORTH AND ARBITRARY 100 ft. GRID, AYRES, LEWIS, NORRIS & MAY INC., ANN ARBOR, MICHIGAN DRAWING 88000-01, 2-17-92

LEGEND:

- SW-1 — SHALLOW GROUND-WATER MONITORING WELL
- P-16 — PIEZOMETER
- WETLANDS
- EW-1 — EXISTING WELL
- 10" — VACUUM DISTRIBUTION CONTOUR (CONTOUR INTERVAL 10" WATER)
- 0.05" — 0.05" THRESHOLD VACUUM CONTOUR (INCHES WATER VACUUM)
- CONTAMINATION ZONE/LETTER

NOTE: ARBITRARY 100 ft. GRID ESTABLISHED BY GERAGHTY & MILLER USING SOUTHWEST CORNER OF PLANT AS 10,000 N/10,000 E AND ALONG WEST WALL AS PLANT NORTH BASELINE. GRID ESTABLISHED ON MARCH 10, 1993.

VAPOR FLOW RATES (CFM)

RW-1	33.0
RW-2	2.5
RW-3	2.5
RW-4	2.5
RW-5	2.5
RW-6	2.5
RW-7	2.5
RW-8	52.0

GERAGHTY & MILLER, INC.
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SCALE VERIFICATION

REV. NO.	DATE	DESCRIPTION	BY	APPR

VAPOR FLOW ANALYSIS IN THE SATURATED ZONE

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HI-MILL MANUFACTURING
HIGHLAND, MICHIGAN

FIGURE A-5

ATTACHMENTS

GROUNDWATER RECHARGE ESTIMATION

The mean monthly recharge can be estimated from the following water balance equation:

$$R = P - RO - E$$

where

R = groundwater recharge
P = precipitation
RO = runoff
E = Evapotranspiration

An upper-bound mean monthly recharge is estimated by neglecting depletion due to runoff. Assuming the mean monthly precipitation is known, groundwater recharge is estimated by calculating mean monthly evapotranspiration values using a standard formula (e.g., Thornthwaite Equation).

The following are the mean monthly temperatures for Pontiac, Michigan from 1987 - 1990 (Table 3.1 Himill Remedial Investigation):

$$january := \frac{25.6 + 23.10 + 31.90 + 32.60}{4} \qquad january = 28.3$$

$$february := \frac{28.8 + 21.8 + 23.0 + 30.0}{4} \qquad february = 25.9$$

$$march := \frac{39.4 + 35.6 + 35.2 + 37.9}{4} \qquad march = 37$$

$$april := \frac{50.5 + 48.1 + 45.7 + 49.3}{4} \qquad april = 48.4$$

$$may := \frac{64.5 + 62.0 + 57.7 + 55.9}{4} \qquad may = 60$$

$$june := \frac{71.6 + 70.9 + 68.1 + 67.5}{4} \qquad june = 69.5$$

$$july := \frac{75.9 + 76.7 + 73.0 + 71.6}{4} \qquad july = 74.3$$

$$august := \frac{70.9 + 73.9 + 71.1 + 70.2}{4} \qquad august = 71.5$$

$$september := \frac{64.7 + 63.3 + 61.9 + 63.0}{4} \qquad september = 63.2$$

$$october := \frac{46.6 + 45.3 + 53.1 + 52.1}{4} \qquad october = 49.3$$

$$november := \frac{32.0 + 40.5 + 37.1 + 42.6}{4} \qquad november = 38.1$$

$$december := \frac{32.0 + 27.6 + 17.3 + 30.8}{4} \qquad december = 26.9$$

Let TF be the mean monthly temperatures in degrees F for Pontiac, Michigan and let TC be the temperatures TF converted to degrees C as follows:

$$TF := \begin{bmatrix} january \\ february \\ march \\ april \\ may \\ june \\ july \\ august \\ september \\ october \\ november \\ december \end{bmatrix}$$

$$TC := \begin{bmatrix} 0.55555\cdot(TF_0 - 32) \\ 0.55555\cdot(TF_1 - 32) \\ 0.55555\cdot(TF_2 - 32) \\ 0.55555\cdot(TF_3 - 32) \\ 0.55555\cdot(TF_4 - 32) \\ 0.55555\cdot(TF_5 - 32) \\ 0.55555\cdot(TF_6 - 32) \\ 0.55555\cdot(TF_7 - 32) \\ 0.55555\cdot(TF_8 - 32) \\ 0.55555\cdot(TF_9 - 32) \\ 0.5555\cdot(TF_{10} - 32) \\ 0.5555\cdot(TF_{11} - 32) \end{bmatrix} \quad TC = \begin{array}{ll} \left[\begin{array}{r} -2.056 \\ -3.389 \\ 2.792 \\ 9.111 \\ 15.569 \\ 20.847 \\ 23.5 \\ 21.958 \\ 17.347 \\ 9.597 \\ 3.361 \\ -2.819 \end{array}\right] & \begin{array}{l} \\ \\ \text{march} \\ \text{april} \\ \text{may} \\ \text{june} \\ \text{july} \\ \text{august} \\ \text{september} \\ \text{october} \\ \text{november} \\ \\ \end{array} \end{array}$$

Let i be a vector of monthy Heat Index components (Thornthwaite equation) computed as follows:

$$i := \begin{bmatrix} (.2 \cdot TC_0)^{1.514} \\ (.2 \cdot TC_1)^{1.514} \\ (.2 \cdot TC_2)^{1.514} \\ (.2 \cdot TC_3)^{1.514} \\ (.2 \cdot TC_4)^{1.514} \\ (.2 \cdot TC_5)^{1.514} \\ (.2 \cdot TC_6)^{1.514} \\ (.2 \cdot TC_7)^{1.514} \\ (.2 \cdot TC_8)^{1.514} \\ (.2 \cdot TC_9)^{1.514} \\ (.2 \cdot TC_{10})^{1.514} \\ (.2 \cdot TC_{11})^{1.514} \end{bmatrix}$$

The Thornthewaite Heat Index I is the following sum for months with temperatures above freezing:

POSMONTH := 2 .. 10 (i.e., months with above freezing mean temperatures)

$$I := \sum_{POSMONTH} i_{POSMONTH}$$

Let a = Thornthwaite equation power as defined as follows:

$$a := 6.75 \cdot 10^{-7} \cdot I^3 - 7.71 \cdot 10^{-5} \cdot I^2 + 1.79 \cdot 10^{-2} \cdot I + 0.49239$$

Let F45 be the latitude/month correction factor for the 45th parallel as tabulated in de Marsily (1986) and given as:

$$F_{45} := \begin{bmatrix} .8 \\ .81 \\ 1.02 \\ 1.13 \\ 1.28 \\ 1.29 \\ 1.31 \\ 1.21 \\ 1.04 \\ .94 \\ .79 \\ .75 \end{bmatrix}$$

Evapotranspiration is calculated for month j using the Thornwaite equation (ignoring months with below freezing mean monthly temperatures) as follows:

$$ET(j) := 1.62 \cdot \left(10 \cdot \frac{TC_j}{I}\right)^{a} \cdot F_{45_j}$$

Assuming evapotranspiration is negligible at the site during the months of January, February, and December, due to the fact that the mean temperatures during these months is sub-freezing, let E be a vector of monthly evapotranspiration values in centimeters as follows:

$$E := \begin{bmatrix} ET(2) \\ ET(3) \\ ET(4) \\ ET(5) \\ ET(6) \\ ET(7) \\ ET(8) \\ ET(9) \\ ET(10) \end{bmatrix} \qquad E = \begin{bmatrix} 0.876 \\ 4.157 \\ 9.102 \\ 13.135 \\ 15.457 \\ 13.133 \\ 8.447 \\ 3.686 \\ 0.852 \end{bmatrix}$$

The following are the mean monthly precipitation values in inches for Pontiac, Michigan from 1987 - 1990 (Talbe 3.1 Himill Remedial Investigation):

$$P_{march} := \frac{2.15 + 0.95 + 1.76 + 2.34}{4} \qquad P_{march} = 1.8$$

$$P_{april} := \frac{1.76 + 2.07 + 0.85 + 2.47}{4} \qquad P_{april} = 1.8$$

$$P_{may} := \frac{2.53 + 0.90 + 2.37 + 4.15}{4} \qquad P_{may} = 2.5$$

$$P_{june} := \frac{5.43 + 0.69 + 5.81 + 2.89}{4} \qquad P_{june} = 3.7$$

$$P_{july} := \frac{3.89 + 6.53 + 0.91 + 1.61}{4} \qquad P_{july} = 3.2$$

$$P_{august} := \frac{4.54 + 3.93 + 3.18 + 4.82}{4} \qquad P_{august} = 4.1$$

$$P_{september} := \frac{2.54 + 3.59 + 4.17 + 5.15}{4} \qquad P_{september} = 3.9$$

$$P_{october} := \frac{2.75 + 4.03 + 2.63 + 4.17}{4} \qquad P_{october} = 3.4$$

$$P_{november} := \frac{2.82 + 3.98 + 2.48 + 3.30}{4} \qquad P_{november} = 3.1$$

Let P be the mean monthly precipitation values in centimeters representative of the site during above-freezing months) as follows:

$$P := \begin{bmatrix} P_{march} \cdot 2.54 \\ P_{april} \cdot 2.54 \\ P_{may} \cdot 2.54 \\ P_{june} \cdot 2.54 \\ P_{july} \cdot 2.54 \\ P_{august} \cdot 2.54 \\ P_{september} \cdot 2.54 \\ P_{october} \cdot 2.54 \\ P_{november} \cdot 2.54 \end{bmatrix} \qquad P = \begin{array}{c} \begin{bmatrix} 4.572 \\ 4.54 \\ 6.318 \\ 9.411 \\ 8.217 \\ 10.458 \\ 9.811 \\ 8.623 \\ 7.988 \end{bmatrix} \end{array} \begin{array}{l} \text{march} \\ \text{april} \\ \text{may} \\ \text{june} \\ \text{july} \\ \text{august} \\ \text{september} \\ \text{october} \\ \text{november} \end{array}$$

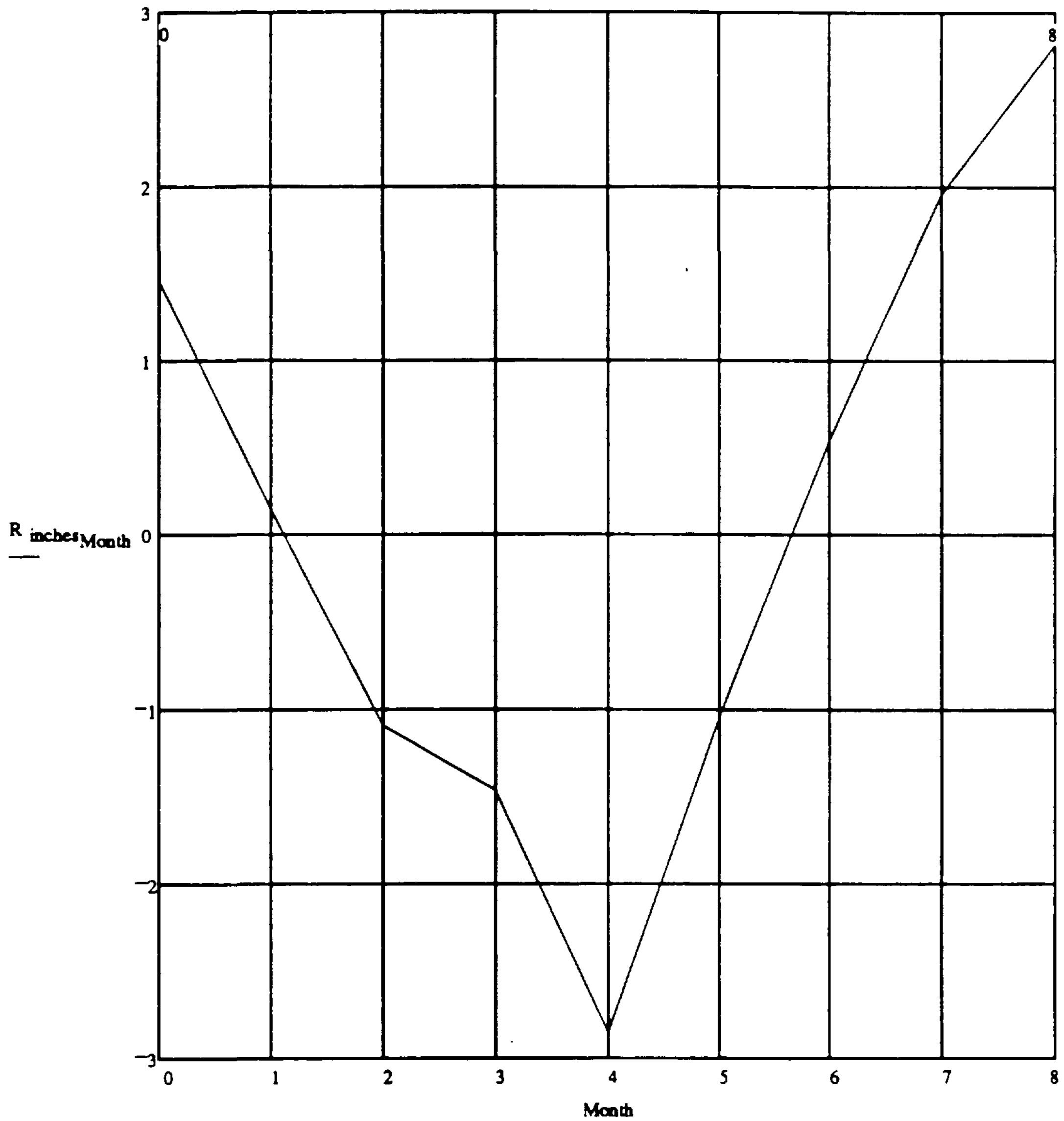
Neglecting runoff of precipitation, groundwater recharge becomes:

$$R := P - E$$

$$R = \begin{bmatrix} 3.696 \\ 0.384 \\ -2.783 \\ -3.725 \\ -7.24 \\ -2.675 \\ 1.364 \\ 4.937 \\ 7.136 \end{bmatrix} \qquad R_{inches} := \frac{R}{2.54}$$

$$R_{inches} = \begin{bmatrix} 1.455 \\ 0.151 \\ -1.096 \\ -1.466 \\ -2.85 \\ -1.053 \\ 0.537 \\ 1.944 \\ 2.81 \end{bmatrix}$$ Groundwater Recharge in inches per month

For Month $:= 0..8$ where 0 is March and 8 is November, groundwater recharge is plotted during the above-freezing months as follows:



MAR APR MAY JUN JUL AUG SEP OCT NOV

$$\text{Net\_Recharge} := \sum_{\text{Month}} R\ \text{inches}_{\text{Month}} \qquad \text{Net\_Recharge} = 0.431 \quad \text{inches per month}$$

Annual Net Recharge: $\text{ANR} := \text{Net\_Recharge} \cdot 9$

$\text{ANR} = 3.9$ inches per year

$\dfrac{\text{ANR}}{4380} = 0.00089$ feet per day

REFERENCES

de Marsily, G. 1986. Quantitative Hydrogeology: Groundwater Hydrology for Engineers. Academic Press, Inc., New York.

APPENDIX B

ARARs LISTINGS

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	*Summary of Requirement*	*Media*	
		Soil	*Ground Water*
MIOSHA Occupational Safety Standards (Part 1 - 18)	Standards for the provision of a safe work environment.	X	X
MIOSHA Construction Safety Standards (Part 1 - 30)	Safety standards for construction activities.	X	X
MPHC Act 368, Part 127	Regulates construction of private drinking water and monitoring wells.		X
MDOT Regulations	Regulations and permit requirements for construction within a state thoroughfare right-of-way.		X
Act 203	Goemaere-Anderson Wetlands Protection Act providing regulations and permit requirements for certain actions taken within a wetland.		X
Act 136	Liquid Industrial Control Act providing regulations and permit requirements regarding the offsite transport of industrial liquids and liquid wastes.	X	X
Act 315	Mineral Well Act providing regulations and permit requirements regarding the construction and abandonment of mineral wells.		X
Act 346	Inland Lakes and Streams Act providing regulations and permit requirements regarding certain construction activities in inland lakes and streams.		X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media	
		Soil	Ground Water
Chemical-Specific ARARs			
Federal			
40 CFR 264.94	Ground water concentration limits for hazardous substances.		X
SDWA 40 CFR 141.11 - .16	Primary drinking water standards / Maximum Contaminant Levels.		X
CAA 109 40 CFR 50	National ambient air quality standards.	X	X
CAA 112 40 CFR 61	National emissions standards for hazardous air pollutants.	X	X
CWA 402 40 CFR 122 123 125	USEPA requirements for NPDES; state NPDES programs; criteria and standards for NPDES.		X
CWA 304	Development and publication of water quality criteria.		X
State of Michigan			
SDWA Act 399 R 324.10601 - 10607	Equivalent to Federal MCL regulations.		X
MWRCA Act 245 R 323.1041 - .1116	Surface water quality standards.		X
R 323.2201 - .2211	Nondegradation of ground-water quality rules.		X
MWRCA 323.6(1)	Unlawful discharge into state waters.		X
Act 307 Parts 7 R 299.5701 - .5727	Cleanup criteria standards.	X	X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media	
		Soil	Ground Water
APA Act 348 Section 2 R 336.1101 - .1126	Definitions of air contaminants.	X	X
HWMA Act 64 R 299.9612	Incorportates Federal MCLs from a regulated facility.		X
Act 154 (MIOSHA) Rules 2101 - 2420	Maximum acceptable workplace concentrations for several chemicals.	X	X
Location-Specific ARARs			
Federal			
40 CFR 264.18b 40 CFR Pt. 6 Appendix A	Location standards; location in a floodplain	X	X
36 CFR Part 62	Protection of natural national landmarks.	X	X
36 CFR Part 65	Protection of historical national landmarks.	X	X
36 CFR Part 800	Protection of historical and cultural properties.	X	X
36 CFR Part 296 43 CFR Part 7 32 CFR Part 229 18 CFR Part 1312	Protection of archeological resourses.	X	X
16 U.S.C. 1531 50 CFR Part 17, 81, 222, 225, 402, 450 - 453	Endangered Species Act.	X	X
16 U.S.C. 1661 Note	Fish and Wildlife Coordination Act.	X	X
16 U.S.C. 2901 50 CFR Part 83	Fish and Wildlife Conservation Act.	X	X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media	
		Soil	Ground Water
33 CFR Parts 320 - 330	U.S. Army Corps of Engineers rules regarding permitting for certain work within waters of the United States.		X
40 CFR Part 6	Environmental impacts of USEPA-related activities.	X	X
40 CFR Part 264.18a - 18c	RCRA location standards for TSDs.	X	X
Executive Order 11988	Floodplain management.	X	X
Executive Order 11990	Wetlands protection procedures.	X	X
State of Michigan			
HWMA Act 64 R 299.9603	Location standards for new or modified TSDs.	X	X
Act 203 Section 281.705	Prohibits certain activities in a wetland without a permit.	X	X
R 281.921 - .925	Rules for obtaining permits and mitigating wetland impacts.	X	X
Act 203, Section 3 R 299.1021 - .1028	Listing of endangered species.	X	X
Act 346 Section 3 R 281.811 - .846	Inland Lakes and Stream Act, prohibits certain activities in the bottomland of a lake or stream without a permit, provides permitting rules.		X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media: Soil	Media: Ground Water
Action-Specific ARARs			
Federal			
40 CFR 260 - 267, 270	Resource Conservation and Recovery Act (RCRA) hazardous waste regulations for treatment, storage, and disposal facilities (TSDs).	X	X
40 CFR 268	Land disposal restrictions.	X	X
CAA 109 111 112	Clean Air Act national ambient air quality standards and national emission standards for hazardous air pollutants.	X	X
40 CFR 51.160 - .164 52 51.166 50.1 - 50.12 61.01 - 61.252	Clean Air Act review of new sources and modifications; approval and promulgation of implementation plans; soil handling; and standards for specific air pollutants.	X	X
33 CFR 320 - 330 33 U.S.C. 403	Rivers and Harbors Act expressing the Army Corps of Engineers policies and procedures associated with construction in waterways.	X	X
40 CFR 122 125 129 136 403	Clean Water Act (CWA) regulations containing provisions regarding the National Pollutant Discharge Elimination System (NPDES); effluent standards for certain toxic pollutants; and pretreatment regulations for new sources of pollution.		X
29 CFR 1910	OSHA operational guidelines and training requirements for workers at hazardous waste sites.	X	X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media	
		Soil	Ground Water
State of Michigan			
R 299.9501 - 9523	Permits and operating licensing for TSD facilities.	X	X
R 299.9601	Applicability standards for TSD rules.	X	X
R 299.9602	Environmental and human health standards for TSDs.	X	X
R 299.9604	TSD design and operating standards.	X	X
R 299.9605	General requirements for operating a TSD facility.	X	X
R 299.9606	Preparadeness and prevention rules for TSD facilities (same as 40 CFR 230.63 - 264.37)	X	X
R 299.9607	TSD contingency plan and emergency procedures requirements as expressed in 40 CFR 264.50 - 264.56.	X	X
R 299.9608	Manifesting requirements for TSD facilities.	X	X
R 299.9609	Recordkeeping requirements for TSD facilities.	X	X
R 299.9610	Reporting requirements for TSD facilities.	X	X
R 299.9611 - .9612	Monitoring requirements for TSD facilities.	X	X
R 299.9613	Closure and post-closure care for TSD facilities.	X	X
R 299.9614	Use and management of hazardous waste storage containers.	X	X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	*Summary of Requirement*	*Media*	
		Soil	*Ground Water*
R 299.9627	Land disposal restrictions (see also 40 CFR 268).	X	X
R 336.1201 - .1285	Air Pollution Act (APA) new source permitting and waiver requirments.	X	X
R 336.2001 - .2033	APA intermittant testing and sampling requirements.	X	X
R 336.201 - .205	APA annual reporting requirements and fee structure.	X	X
R 336.1301 - .1331 336.1370 - .1373	APA particulate matter emissions limitations and prohibitions.	X	
R 336.1701 - .1710	APA new VOC source emissions limitations and prohibitions.	X	X
R 336.1901 - .1912	APA miscellaneous emissions limitations and prohibitions.	X	X
R 325.11001 - .11009	Safe Drinking Water Act (SDWA) treatment system requirments for drinking water suppliers.		X
R 325.11301 - .11311	Permitting and construction plans and specifications requirements for modifiers or constructors of a Type I or II water supply system.		X
R 325.11901 - .11918	Requirements for the classification of water distributions systems and operator examination and certification requirements.		X
R 325.12101 - .23110	Approval requirements for drinking water treatment system materials and chemicals.		X
R 323.1231 - .1236	Wastewater reporting requirements.		X

Table B-1. Potential ARARs, Hi-Mill Manufacturing Site.

Potential ARAR	Summary of Requirement	Media	
		Soil	Ground Water
R 323.1251 - .1259	Supervision rules for wastewater dischargers to surface or ground waters.		X
R 323.2102 - .2109	Wastewater discharge permitting requirements.		X
R 323.2201 - .2211	Nondegradation of ground-water quality rules.		X
R 323.1311 - 1329 MWRCA 323.5a - .5b	Construction in floodplains.	X	X
MWRCA 323.6(1)	Unlawful discharge into state waters.		X
Act 347 R 323.1701 - .1714	Soil erosion and sediment control.	X	X
Act 98 R 299.2901 - .2927	Classification of sewage and waste treatment plants; certification of operators.		X
R 299.2931 - .2945	Permitting for sewage system, plans and specifications approval process.		X
R 299.2951 - .2960	Sewage plant O&M rules.		X
Act 307 Parts 1 - 8 R 299.5101 - .5607 R 299.5801 - .5823	State Superfund program addressing risk evaluation, cleanup criteria, and response activities at uncontrolled hazardous waste sites.	X	X
Act 127	Protection of natural resources from pollutants, impairment, and destruction.	X	X
Act 154 (MIOSHA) Rules 1101 - 5007	Standards for the provision of a healthful work environment.	X	X

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A* *On-Site Treatment Configuration*	*Alternative 3B* *On and Off-Site Treatment Configuration*
Federal Action-Specific ARARs		
40 CFR 268 Land disposal restrictions.	If hazardous waste is generated during the treatment process, (e.g., with the optional carbon treatment of off-gases), the disposal will comply with this ARAR.	If hazardous waste is generated during the treatment process, (e.g., with the optional carbon treatment of off-gases), the disposal will comply with this ARAR.
Clean Air Act (CAA) CAA 109 CAA 111 CAA112 40 CFR 50-52, 61	Will comply with substantive requirements of the Clean Air Act.	Will comply with substantive requirements of the Clean Air Act.
Clean Water Act (CWA) 40 CFR 122, 125, 129, 136, 403	Water treatment discharges will comply with the substantive requirements of these Clean Water Act (CWA) regulations containing provisions regarding the National Pollutant Discharge Elimination System (NPDES); effluent standards for certain toxic pollutants; and pretreatment regulations for new sources of pollution.	Water treatment discharges will comply with the substantive requirements of these Clean Water Act (CWA) regulations containing provisions regarding the National Pollutant Discharge Elimination System (NPDES); effluent standards for certain toxic pollutants; and pretreatment regulations for new sources of pollution.
Occupational Safety & Health Adminsitration (OSHA) 29 CFR 1910	Work will comply with OSHA operational guidelines and training requirements for workers at hazardous waste sites.	Work will comply with OSHA operational guidelines and training requirements for workers at hazardous waste sites.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A* *On-Site Treatment Configuration*	*Alternative 3B* *On and Off-Site Treatment Configuration*
State of Michigan Action-Specific ARARs		
Act 64 Hazardous Waste Management Act (HWMA) Rules and Regulations for TSD facilities.	Potentially applicable due to the treatment of ground water that may be considered a hazardous waste, and the potential generation (and subsequent off-site transport and disposal) of carbon that may be considered a hazardous waste.	Potentially applicable due to the treatment of ground water that may be considered a hazardous waste, and the potential generation (and subsequent off-site transport and disposal) of carbon that may be considered a hazardous waste.
R 299.9627 Land Disposal Restrictions	Will comply with land disposal restrictions (see also 40 CFR 268 above).	Will comply with land disposal restrictions (see also 40 CFR 268 above).
Michigan Air Pollution Control Act Act 348 R 336.1201 - .1285 R 336.2001 - .2033 R 336.201 - .205 R 336.1301 - .1331 R 336.1370 - .1373 R 336.1701 - .1710 R 336.1901 - .1912	Water and vapor treatment system and construction activities will comply with the substantive Air Pollution Act (APA) emissions and testing requirements. Carbon treatment of the off-gas will be performed, if necessary, to comply with the substantive requirements of these rules.	Water and vapor treatment system and construction activities will comply with the substantive Air Pollution Act (APA) emissions and testing requirements. Carbon treatment of the off-gas will be performed, if necessary, to comply with the substantive requirements of these rules.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A* *On-Site Treatment Configuration*	*Alternative 3B* *On and Off-Site Treatment Configuration*
MWRCA - Act 245	Will meet these ARARs dealing with state water quality standards, wastewater discharge rules, and nondegradation of ground-water. (Water treatment for this alternative will consist of source containment with on-site ground-water extraction along with subsequent treatment and discharge to a surface-water body.)	Will meet these ARARs dealing with state water quality standards, wastewater discharge rules, and nondegradation of ground-water. (Water treatment for this alternative will consist of both on-site ground-water source containment and extraction of off-site ground water with subsequent treatment and discharge to a surface-water body.)
SESCA - Act 347 R 323.1701 - .1714	These soil erosion and sediment control requirements are applicable because the construction of the treatment unit may involve movement of earth that could effect erosion. The alternative will meet these ARARs.	These soil erosion and sediment control requirements are applicable because the construction of the treatment unit and trenching activities taking place in the median of M-59 may involve movement of earth that could effect erosion. The alternative will meet these ARARs.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A On-Site Treatment Configuration*	*Alternative 3B On and Off-Site Treatment Configuration*
MERA Act 307 Parts 1 - 8 R 299.5515 R 299.5101 - .5607 R 299.5801 - .5823	These state Superfund rules are applicable because a remedial action is taking place at the site, and the site is an Act 307 facility. This alternative will comply with Act 307, and will result in a type C cleanup of soil and ground water using active soil treatment on and off the site, ground-water treatment on-site to control the source, and ground-water monitoring and deed restrictions on and off-site to limit potential exposure to impacted ground water.	These state Superfund rules are applicable because a remedial action is taking place at the site, and the site is an Act 307 facility. This alternative will comply with Act 307, and will result in a type C cleanup of soil and ground water using active soil treatment, ground-water treatment, monitoring, and deed restrictions on and off-site to limit potential exposure to impacted ground water.
Act 154 (MIOSHA) Rules 1101 - 5007 MIOSHA Occupational Safety Standards (Part 1 - 18) MIOSHA Construction Safety Standards (Part 1 - 30)	These ARARs are applicable because of the construction and operation of treatment equipment that will take place at the site. The alternative will comply with these MIOSHA ARARs.	These ARARs are applicable because of the construction and operation of treatment equipment that will take place at the site. The alternative will comply with these MIOSHA ARARs.
MPHC Act 368, Part 127 Act 315 - Mineral Well Act Drinking water, monitoring, and mineral well construction and abandonment requirements.	Additional monitoring wells will be constructed (and abandoned) to comply with these ARARs.	Additional monitoring wells will be constructed (and abandoned) to comply with these ARARs.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A* *On-Site Treatment Configuration*	*Alternative 3B* *On and Off-Site Treatment Configuration*
Act 203 - Goemaere-Anderson Wetlands Protection Act	Construction activities taking place in wetlands, if required, will meet the substantive requirements of these regulations.	Construction activities taking place in wetlands, if required, will meet the substantive requirements of these regulations.
Act 136 - Liquid Industrial Waste Disposal Act	Any off-site transport of liquid wastes will be conducted in a manner compliant with this ARAR.	Any off-site transport of liquid wastes will be conducted in a manner compliant with this ARAR.
Act 346 - Inland Lakes and Streams Act	If construction is required in applicable waterways, the remedy will be conducted to comply with the substantive requirements of this act.	If construction is required in applicable waterways, the remedy will be conducted to comply with the substantive requirements of this act.
<u>Federal Chemical-Specific ARARs</u>		
Safe Drinking Water Act (SDWA) 40 CFR 141.11 - .16	These primary drinking water standards / Maximum Contaminant Levels (MCLs) are neither applicable nor are they relevant and appropriate because no one is currently drinking the ground water, and due to the shallow perched nature and tight geology of the affected ground-water unit, no one is likely to drink the impacted ground water in the future.	These primary drinking water standards / Maximum Contaminant Levels (MCLs) are neither applicable nor are they relevant and appropriate because no one is currently drinking the ground water, and due to the shallow perched nature and tight geology of the affected ground-water unit, no one is likely to drink the impacted ground water in the future.
CAA 109, 112 40 CFR 50, 61 Clean Air Act Requirements	The water and vapor treatment system will meet the substantive requirements of these national ambient air quality standards and national emissions standards for hazardous air pollutants.	The water and vapor treatment system will meet the substantive requirements of these national ambient air quality standards and national emissions standards for hazardous air pollutants.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A* *On-Site Treatment Configuration*	*Alternative 3B* *On and Off-Site Treatment Configuration*
CWA 402, 304, 40 CFR 122, 123, 125	Water treatment discharge portion of the remedy will meet USEPA requirements for NPDES, state NPDES programs, criteria and standards for NPDES, and the substantive requirements of published water quality criteria.	Water treatment discharge portion of the remedy will meet USEPA requirements for NPDES, state NPDES programs, criteria and standards for NPDES, and the substantive requirements of published water quality criteria.
State of Michigan Chemical-Specific ARARs		
SDWA Act 399 R 324.10601 - 10607	Like the federal MCL regulations, these requirements are not ARARs for this site.	Like the federal MCL regulations, these requirements are not ARARs for this site.
Act 307 Parts 7 R 299.5701 - .5727	The cleanup criteria standards expressed within these rules are ARARs for the site. The cleanup accomplished by this alternative will meet MDNR type C cleanup levels.	The cleanup criteria standards expressed within these rules are ARARs for the site. The cleanup accomplished by this alternative will meet MDNR type C cleanup levels.
Act 154 (MIOSHA) Rules 2101 - 2420	These ARARs include a listing of the maximum acceptable workplace concentrations for several chemicals. The alternative will meet these ARARs.	These ARARs include a listing of the maximum acceptable workplace concentrations for several chemicals. The alternative will meet these ARARs.
Federal Location-Specific ARARs		
None Identified.	None Identified.	None Identified.

Table B-2. Detailed ARARs Analysis, Hi-Mill Manufacturing Site.

Type of ARAR/ARAR Description	*Alternative 3A On-Site Treatment Configuration*	*Alternative 3B On and Off-Site Treatment Configuration*
State of Michigan Location-Specific Standards		
MDOT Permitting Rules for Construction in Right-of-Way	Not an ARAR.	Although the situation is applicable, these permit requirements would technically be waived under a CERCLA action, and therefore this requirement would not be an ARAR. However, interface with MDOT for approval of any construction work to be performed within the right-of-way would likely be necessary.